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PRODUCTION FABRICATION
TREATMENT APPLICATION

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Iron and Steel Engineers to Hold Convention and Exposition in Detroit

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THE Association of Iron and Steel Engineers, formerly the Association of Iron and Steel Electrical Engineers, will hold its 32nd convention and exposition in Detroit, Sept. 22 to 25. The headquarters will be the Statler Hotel where the technical sessions will be held. The iron and steel exposition will be housed in Detroit's Convention Hall on Cass Avenue and will be open each day until 10:00 P.M. About 150 exhibitors have booked space.

An interesting technical program of about 30 papers has been scheduled, interspersed with trips to steel plants and some social affairs. The annual business meeting will be held at 9:15 A.M., Sept. 22. The tentative technical program is as follows:

Tuesday, Sept. 22

Morning:

"Developments in the Iron and Steel Industry During 1935-1936," by W. H. Burr, electrical and mechanical superintendent, Lukens Steel Co., Coatesville, Pa.

"Steel Sheets for Today's Motor Car—Mechanical and Electrical Problems of Fabrication," by Thomas P. Archer, vice president in charge of operations, Fisher Body Co., Detroit, and R. A. Geuder, electrical engineer, Reliance Electric & Engineering Co., Cleveland.

"Developments in the Flat Rolled Steel Industry During 1935-1936," by Stephen Badlam, consulting engineering, Pittsburgh.

"Seasonal and Present Economic Trend of the Automobile Business," by C. E. Wilson, vice president, General Motors Corp., Detroit.

Afternoon:

"The Steel and the Automotive Industries," by B. F. Fairless, president, Carnegie-Illinois Steel Corp., Pittsburgh.

"Material Handling Facilities for Hot and Cold Strip Mills," by Fred M. Gillies, assistant general superintendent, Inland Steel Co., Indiana Harbor, Ind.

"Electrical Applications in Continuous Hot Strip Mills," by L. A. Umansky, industrial engineering department, General Electric Co., Schenectady, N. Y.

"Operation of Runout Tables, Coiler Drives and Adjustable Speed Frequency Sets Interpreted Through the Oscillograph," by F. E. Harrell, assistant chief engineer, and W. R. Hough, Experimental Engineer, Reliance Electric & Engineering Co., Cleveland.

Evening:

Exhibitors' Informal Dance, Hotel Statler.

Wednesday, Sept. 23

Morning:

"Bright Annealing and Normalizing Auto-Body Stock Steel in Electric Furnaces," by F. T. Hague, manager, D. C. engineering department and P. H. Brace, manager, metallurgical department, research division, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

"Sheet and Strip Steel for Deep Drawing Purposes," by Joseph Winlock, chief metallurgist, Edward G. Budd Mfg. Co., Philadelphia.

"Heat Treating Alloy Bar Stock in Electric Furnaces," by Dr. Marcus A. Grossmann, director of research, Carnegie-Illinois Steel Corp., Chicago.

"The Development of the Great Lakes Steel Corporation." by George R. Fink, president, Great Lakes Steel Corp., Ecorse, Mich.

Afternoon:

Inspection trip to Great Lakes Steel Corp., Ecorse, Mich. Special buses which the A. I. & S. E. will provide and which the guests must use, will leave the Hotel Statler at 12:45 P. M. (E.S.T.). Price $2 per person. Tickets available at A. I. & S. E. registration desk or Iron and Steel Exposition office, Convention Hall, Cass Ave.

Thursday, Sept. 24

LUBRICATION ENGINEERING DIVISION

Morning:

"Centralized Lubrication and Roll Cooling Systems," by T. J. Kauffeld, special representative, DeLaval Separator Co., Pittsburgh.

"Lubrication of Steel Mill Equipment," by C. J. Klein, chief engineer, Weirton Steel Co., Weirton, W. Va.

"Some Ideas in Lubrication," by Arthur W. Burwell, technical director, Alox Corp., Niagara Falls, N. Y.

MECHANICAL, ELECTRICAL AND LUBRICATION ENGINEERING DIVISION

Afternoon:

"Developments in Rolling Mills at the Ford Motor Co.," by M. Stone, engineer, United Engineering & Foundry Co., Pittsburgh.

COMBUSTION ENGINEERING DIVISION

Morning:

"Automatic Control in Open-Hearth Furnaces," by A. F. Spitzglass, vice president, Republic Flow Meters Co., Chicago.

"Soaking Pits," by P. M. Office, vice president, Amsler-Morton Co., Pittsburgh.

"The Trend in Refractories Application in the Steel Plant," by A. V. Leun, refractory engineer, Bethlehem Steel Co., Bethlehem, Pa.

"Recuperators for Continuous Slab Heating Furnaces," by W. H. Fitch, manager, recuperator department, Carborundum Co., Perth Amboy, N. J.

Afternoon:

"Gas Distribution at the Ford Motor Co.," by F. J. Harlow, manager, industrial division, Philgas department, Phillips Petroleum Co., Detroit.

"Study of Blast Furnace Charging," by Gordon Fox, vice president, Freyn Engineering Co., Chicago.

"Inhibitors and Their Probable Mechanism," by G. Walter Esau, metallurgical engineer, E. F. Houghton & Co., Philadelphia.

WELDING ENGINEERING DIVISION

Afternoon:

"Development in Welding During 1935-1936," by Grover A. Hughes, electrical engineering, Truscon Steel Co., Youngston, Ohio.

"Resistance Welding in Steel Plants," by Walter Anderson, vice president and Malcomb Clark, general manager, Taylor Winfield Corp., Warren, Ohio.

"How Arc Welding Aids in the Use of Standard Steel Mill Products in the Electrical Industry," by O. A. Tilton, industrial engineering department, General Electric Co., Schenectady, N. Y.

"Commercial Welding as Applied to Steel Mills," by H. A. Woofter, chief engineer, The Federal Machine & Welder Co., Warren, Ohio.

Evening:

Formal reception, Hotel Statler Ball Room.

Friday, Sept. 25

Inspection trip to steel plant, rolling mills and assembly line Ford Motor Co., Detroit. Special buses which the A. I. & S. E. will provide and the guests must use, will leave the Hotel Statler at 9:15 A.M. Price $2 per person. Tickets available at A. I. & S. E. registration desk, Hotel Statler, or Iron and Steel Exposition Office, Convention Hall, Cass Ave.

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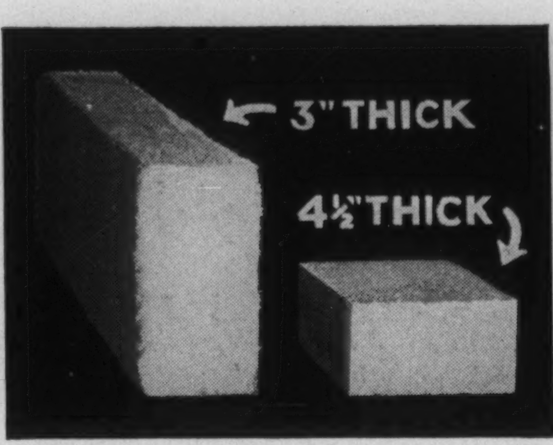

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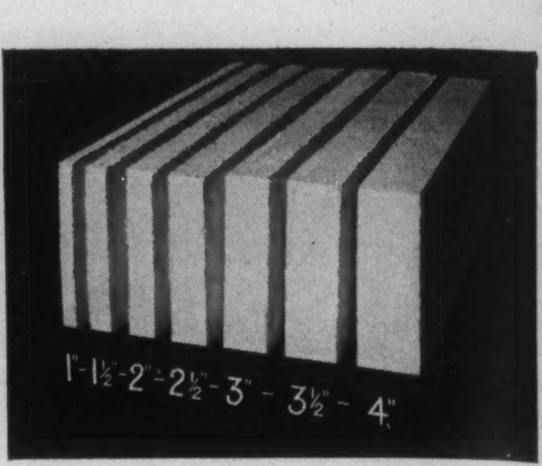

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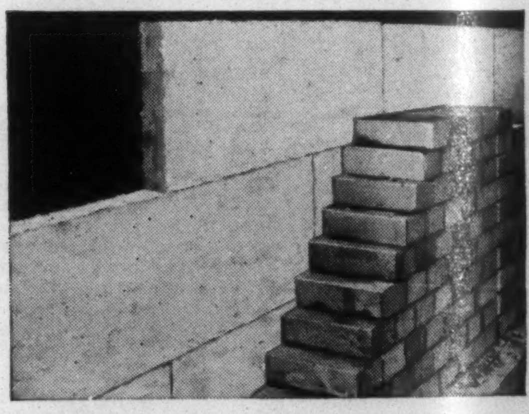

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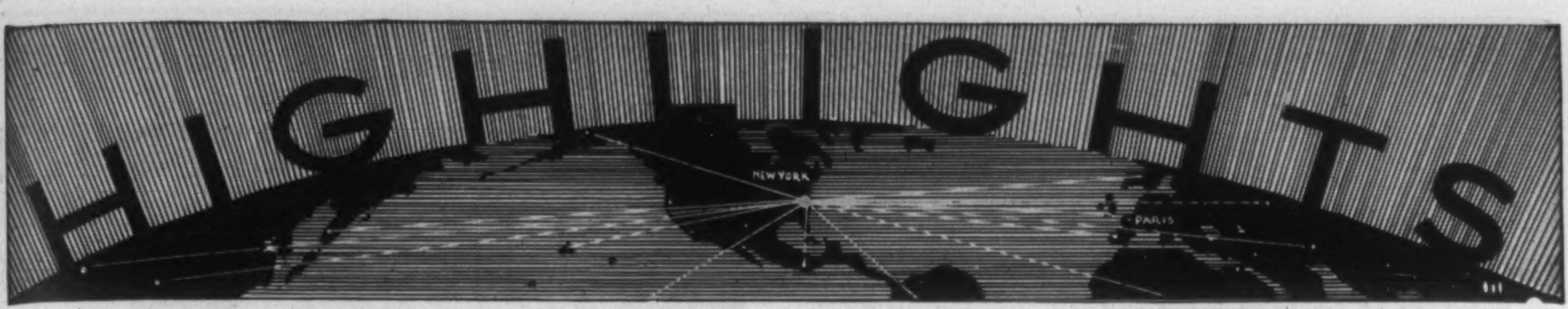

Written by the Abstract Section Editors and the Editorial Staff

DO YOU want to know what metallurgical engineers are saying, the world over? Look in the Current Metallurgical Abstracts. Here are some of the points covered by authors whose articles are abstracted in this issue.

Shock Absorbers

The importance of vibration in reducing the life of furnace refractories is recognized by Hess (page MA 447 L 2) in which he recommends that furnaces be mounted on shock absorbing material.—M.H.M.

More Hot Tubes

Another application of radiating metal tubes fired with gas is described by Spowers (page MA 447 L 3) in which the tubes are applied to a galvanizing pot to prevent local overheating of the pot by preventing direct impingement of the flame.—M.H.M.

Approaching the Original Conception

The original conception of a soaking pit, as the name implies, was a chamber in which the heat in the molten interior of steel ingots was allowed to equalize through the remainder of the ingot, which could only be accomplished in a well insulated chamber. With increases in production, the soaking pit has become more and more a heating furnace with little attention to economy, but Jenkins (page MA 447 L 4) now recommends the use of heat insulation.—M.H.M.

A Warning

It is easy to bend over backward too far in conserving a scarce or expensive metal. Lüder (page MA 449 L 4) warns against cutting the tin content of soft solder too radically since it may result in eventually using more, rather than less, tin.—B.W.G.

Factors Affecting Adhesion of Electrodeposits

Meyer (page MA 454 R 1) gives a lot of good information on factors influencing adhesion of electrodeposits. Cleaning, pickling, and conditions of electrodeposition may be made perfect, but it must be discouraging to try to keep a thin deposit intact when its coefficient of expansion differs widely from that of the underlying metal.—B.W.G.

Design for Welding

The conquest of industry by welding necessarily has been slow. Stubborn resistance has had to be overcome in one field after another. Ultra conservatism has impeded its progress at every turn. But, due largely to this very fact, the results which have been achieved to date are permanent. Growth of the process has been uniform and healthy. The wide application attained by welding, against all opposition, is, in itself, most convincing proof of its inherent merit.

While welding still has far to go before it is universally accepted and adopted for all kinds of suitable work, it is reasonable to expect that eventually this is bound to come about. Ample assurances of the bright future of welding are provided by the record of its phenomenal recent growth, at constantly accelerated rate.

Some idea of the unlimited variety of equipment that welding is used for today may be gained from the article by Davis (page MA 449 L 9). The trend is unmistakable. To stay abreast of modern developments, all-welded constructions are increasingly mandatory. "Design for Welding" is the order of the day.—E.V.D.

Voice of the Departed

"Accelerated" tests for creep seem all the rage abroad. Schmidt and Krainer (page MA 468 L 5) as well as Schmitz (page MA 468 R 2) discuss them, and, according to the latter, German practice is standardized on rate of flow between the 25th and 35th hour. Chevenard (page MA 468 L 2) also uses that period. Fittingly, Chevenard's discussion was presented at a Séance. As for us, we'd just as soon take the guess of a "medium" at a clairvoyant séance on the load carrying ability in service as the result of a 25-35th hour "test." Anyhow the N.P.L. haven't fallen for this type of wishful thinking, and sanity will finally win out abroad as a result of its example and the data it presents. —H.W.G.

External Conditions versus Protective Coatings

The most important fact developed during recent years from an industrial standpoint is the importance of differences in the conditions of exposure. This fact has again been demonstrated in the case of protective coatings by the work of Blum, Strausser and Brenner (page MA 469 L 2). Under rural or marine climatic conditions zinc and cadmium coatings gave better protection to iron than nickel and chromium while in an industrial atmosphere, where sulphurous and sulphuric acids are present, the reverse was true.—V.V.K.

Ferromagnetic Theory: A Fairly Easy Lesson

Unwillingly perhaps, but nevertheless surely, the metallurgist is being forced more and more to acquaint himself with ferromagnetism. To those who already see the writing on the wall there can be recommended Bozorth's article (page MA 458 R 2): this reader knows of no other that is so comprehensible and so richly rewarding. It must be stated, to be sure, that "The Present Status of Ferromagnetic Theory" cannot be digested with the effort required to read the sports page; the point is that Bozorth has put handles on the concepts which exist for the mathematical physicist as differential equations or worse. This, if you have never tried it, is no small accomplishment. Incidentally, because of the high compression of the abstract, the article seems tougher than it really is.—J.S.M.

Hydrogen in Steel

Since hydrogen is often blamed when flakes show up these days, and since flakes are apt to be a matter of national defense in those countries indulging in the armament race, Ploum's article (page MA 458 L 8) is of interest even though he was not concerned with flakes. However, by reviewing the literature and by presenting his own observations on the mechanisms of hydrogen absorption and expulsion, Ploum has lightened the task of those who may have to determine how much there is in the notion that hydrogen may ruin a batch of gun forgings.—J.S.M.

"Balance" in a Steel

Prohoroff suggests an interesting type of "balance" in a steel whereby alloying elements of opposing tendencies upon diffusion of C are used in order to avoid banded structure (page MA 458 L 10). Perhaps it is easier said than done.—H.W.G.

Fireproof Photographic Reproductions

Jenny describes how aluminum oxide films (produced on sheets) may be sensitized and used for the reproduction of images by following conventional photographic technique (page MA 472 L 6). It is claimed that the "negatives" are resistant to fire, heat, organic solvents and abrasion. (?)—G.L.C.

Data on Binary Alloys

An unusually complete compilation of information on the constitution and structure of binary alloys has been made by M. Hansen (page MA 458 L 2). It is enthusiastically recommended by Mehl as a particularly valuable reference book for research metallurgists.—B.W.G.

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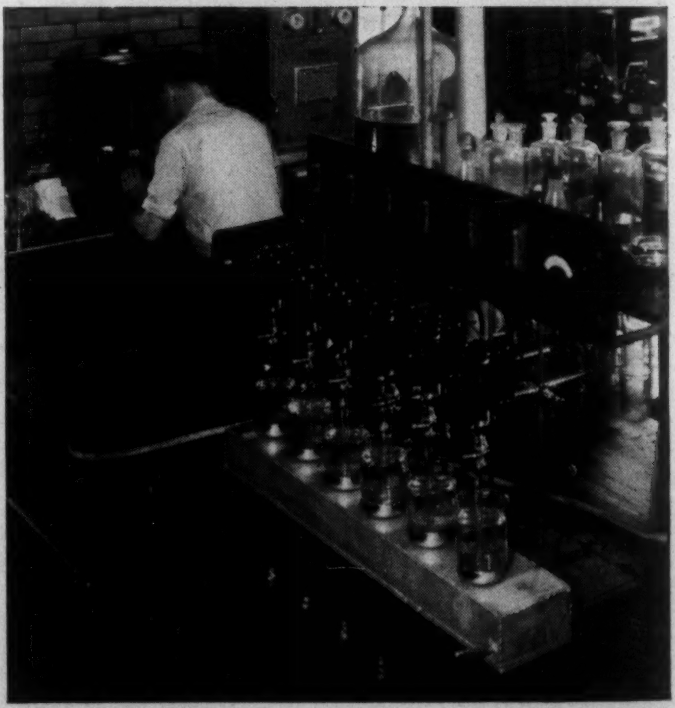

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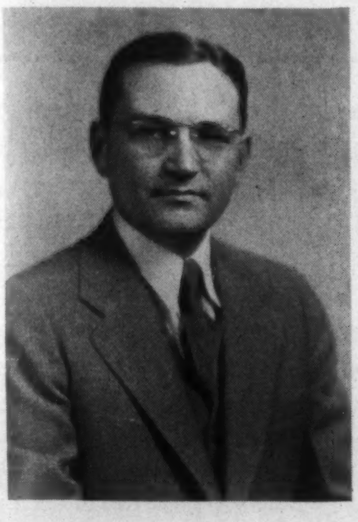
Our Section Editors

(Continued from the July and August Issues)

M. GENSAMER is assistant professor of metallurgy at Carnegie Institute of Technology, Pittsburgh. He is also a part-time member of the staff of the Metals Research Laboratory of that institution. He was graduated from Carnegie in 1924 with the degree of B.S. in metallurgy. After working for five years as metallurgist for the American Chain Co. at its Page Steel Wire Co. plant at Monessen, Pa., he returned to Carnegie in 1929 as a member of the staff of the Metals Research Laboratory. In 1931 he received his M.S. degree (with distinction), and his D. Sc. degree in metallurgy in 1933. He was appointed to his present position in 1935.

Dr. Gensamer is a member of the American Society for Metals and the American Institute of Mining and Metallurgical Engineers, and is also secretary of the Pittsburgh Science of Metals Club. He was a joint recipient of the Howe Medal with Drs. Walters, Wells and Eckel for work on alloys of iron, manganese and carbon. He has published papers on Fe-Mn-C alloys, on the deformation textures in rolled steel, an X-ray study of Lüders lines in mild steel, and on internal stresses by X-ray methods.



M. Gensamer

OSCAR E. HARDER is assistant director of Battelle Memorial Institute, Columbus, Ohio. He obtained his B.A. and his M.S. in chemistry degrees from the University of Oklahoma. The University of Illinois bestowed a Ph.D. degree on him in 1915 for special work in applied and organic chemistry, as well as in geology, French and German.

Dr. Harder has had a broad experience as a teacher, having been connected with the University of Oklahoma, of Kansas and of Illinois, where he had a fellowship from 1913 to 1915. He was professor of metallography at the University of Minnesota from 1919 to 1930. He has done a great deal of consulting work for many firms on gold alloys, drill rod, bearing metals, rails, steel castings, and so on.

The following societies number him among their members: A.S.M., A.C.S., A.S.T.M., A.I.M.E., Amer. Assn. for Adv. of Science and the Soc. for Prom. Eng. Education. Dr. Harder was the Howe Medalist of the A.S.S.T. (now A.S.M.) in 1928. He was a national director of that society from 1930 to 1932, and he is a member of a number of A.S.T.M. committees.

Oscar E. Harder

Dr. Harder has contributed many technical papers to various societies. His special interests include metallography, X-ray work, high and low temperatures of metals, dental alloys, carburizing and nitriding. He is in charge at Battelle of projects on metallography, physical metallurgy, and the control of the physical properties of metals.

H. W. GRAHAM is general metallurgist of the Jones & Laughlin Steel Corp., Pittsburgh. He was graduated from Lehigh University, Bethlehem, Pa., in metallurgy in 1914 and has been continuously connected with his present employer ever since. For the first five years of this period he was engaged in operating work in various departments, particularly the blast furnace, open-hearth and Bessemer. From 1919 to date he has held various positions in metallurgical work. Since 1928 he has had supervisory charge of all technical affairs of the Corporation.

H. W. Graham

Mr. Graham has devoted considerable time for over 15 years to a study of the machinability and the manufacture of open-hearth and Bessemer screw steels, and has written a number of papers on the subject. For some years also he has made a "professional hobby" of rotary drill pipe for oil well use. He has originated a number of developments in this field and contributed papers thereon.

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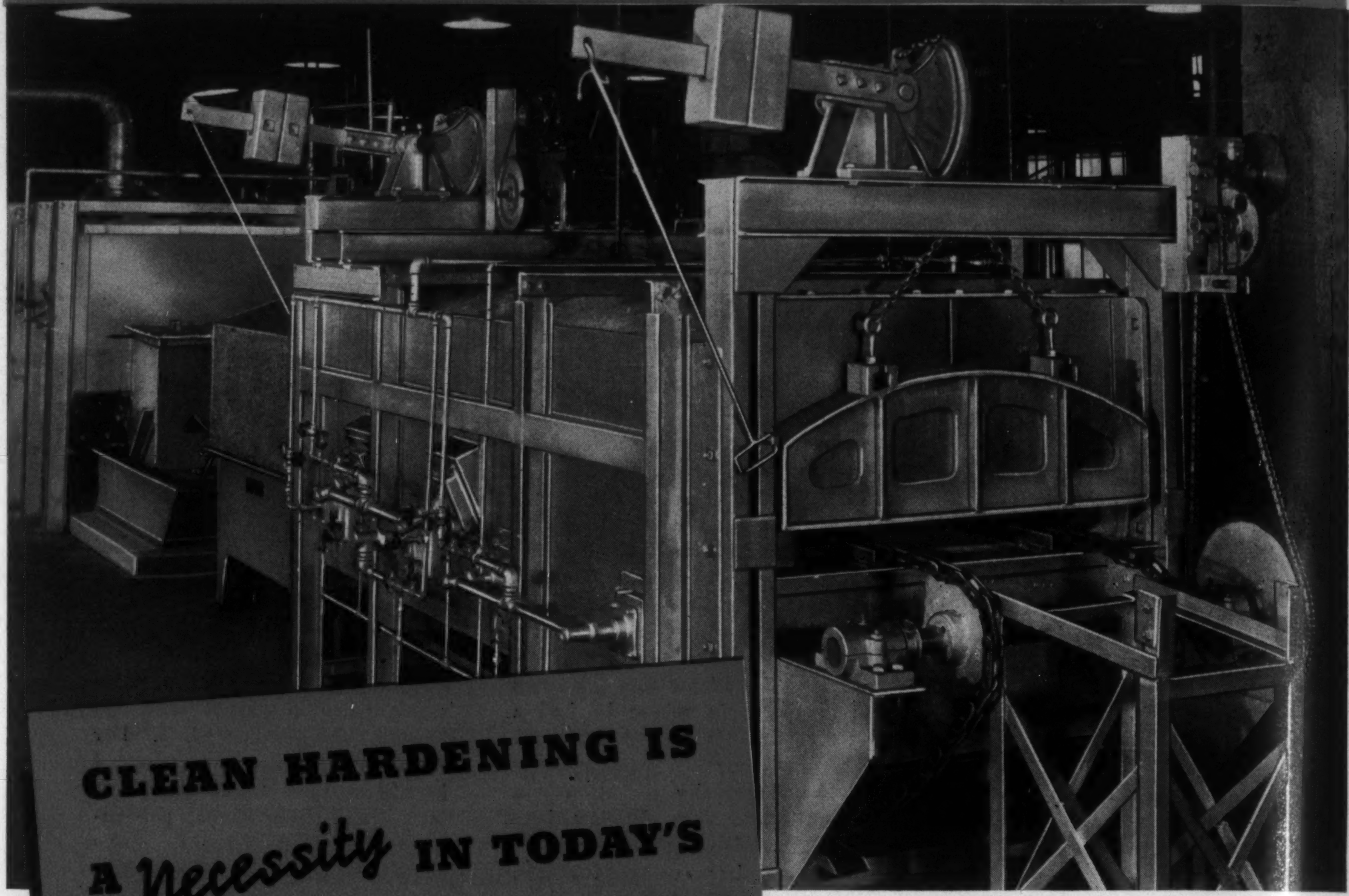

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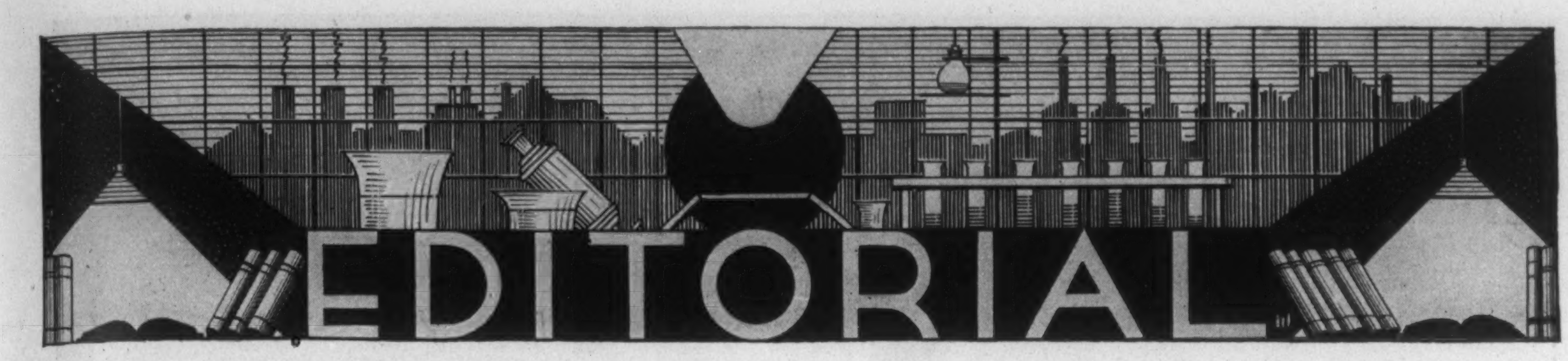

Gnats and Camels

CLARK[1] has cited a case where the creep resistance at 850 deg. F. of two steels of very similar analysis were respectively 7,000 and 12,000 lbs. per sq. in. and points out that the one with the lower value was "the usual run of commercial steel," while the other, a carbon steel, was "made according to best alloy steel practice." He indicates that there will be a difference according to whether the steel is made by the induction, the air or the open-hearth process.

Kinzel[2] points out that killed steels have better creep properties than semi-killed or rimmed steel.

Whitney[3] said that tubing of the same grade, from different manufacturers, may vary as much as the figures given by Clark. Robinson of the G. E. Co., in unpublished discussion at meetings of the Joint High Temperature Committee of the A.S.T.M. and A.S.M.E., has since reported variations fully as great, and differences of that magnitude are within the experience of most laboratories which have done much creep testing on steels whose composition, room temperature properties and short-time high temperature properties are close together.

In the report of the National Physical Laboratory for 1935[4] it is remarked that in work on high temperature structural stability of 0.15 per cent carbon steel, the first lot tried had an abnormally high creep rate at 840 deg. F. and was then substituted by one with a more normal rate of creep.

As long as there was a considerable variation in the care taken by different laboratories in creep testing, some such discrepancies that were noted early, were ascribed to variations in testing technique and it was assumed that the steels were not responsible for the variation. Too many cases are now on record where any one laboratory finds variations far outside its probable errors of testing, for this idea to be tenable any longer. Steels, apparently alike in other respects, and marketed for the same purposes, evidently do vary a lot in their long-time load-carrying ability at high temperature. When such results are obtained on steels bought on the open market, without a clear record of every variable in their manufacture, the tests are useful for selecting a creep-resistant lot, but worthless for throwing light on why it was or was not creep-resistant. If anyone has intentionally varied the conditions of manufacture of steel for high temperature use and made enough creep tests to show a correlation between those conditions and the creep properties, he is keeping pretty quiet about it.

Yet, the problems of hardenability and "body", equally mysterious not so long ago, are yielding to study and steels of controlled grain size and known hardenability are being produced at will. What controls the creep properties is probably no more occult.

Since the differences seem only to be shown by long-time creep tests, those countries abroad that have yielded to wishful thinking and are attempting to use so-called accelerated tests to evaluate long-time properties, are not likely to obtain information of any value on the problem. It would be a rather expensive job to handle in proper fashion, but it must be done sooner or later if we are to make engineering progress in high temperature uses of steel.

Those who make, test and use steel at high temperatures are often haggling over matters that are of much less fundamental importance than this.

The most complete statement of the situation is in an article "Some Aspects of the Behavior of Carbon and Molybdenum Steels at High Temperatures" by Jenkins, Tapsell, Mellor and Johnson of the National Physical Laboratory, presented at the Chemical Engineering Congress of the World Power Conference this summer. Four 0.13 to 0.20 per cent C steels, similarly heat-treated, loaded at 8 tons per sq. in. for 20 days stretched on the average about ¼ of 1 per cent, but one 0.16 per cent C steel stretched 7 per cent, and one 0.19 per cent C steel over 1 per cent i.e., 28 and four times as much respectively as the others. In 0.40 per cent C steels, similarly loaded, half a dozen averaged a total stretch of 0.3 per cent, but a seventh stretched 1.3 per cent, or four times as much. If comparisons are made on the rate of creep at the end of 20 days, the two erring low carbon steels were stretching 134 and 13 times as fast as the average of the good ones, while the black sheep of the 0.40 per cent carbon steels outran its companions 13 to 1.

While some details of the melting and deoxidation practices are known and recorded, the controlling variables are still obscure. One of the poor low carbon steels was acid open-hearth without addition of aluminum, while two of the good ones were an oper-hearth, one with and one without aluminum.

The bad 0.40 per cent C steel was basic electric arc, with aluminum addition, and a very good one was basic electric arc, with titanium addition. No one recorded variable upon which blame could be heaped fails to show an alibi in some other lot. That the trouble goes back to the original melt is indicated by work on castings where a good and a bad lot remained good or bad in creep regardless of whether the steels were tested as castings or in wrought form.

It seems time that those interested in the problem cease straining at gnats while swallowing the camel. The situation has been on record for five years, with nothing much done about it.—H. W. G.

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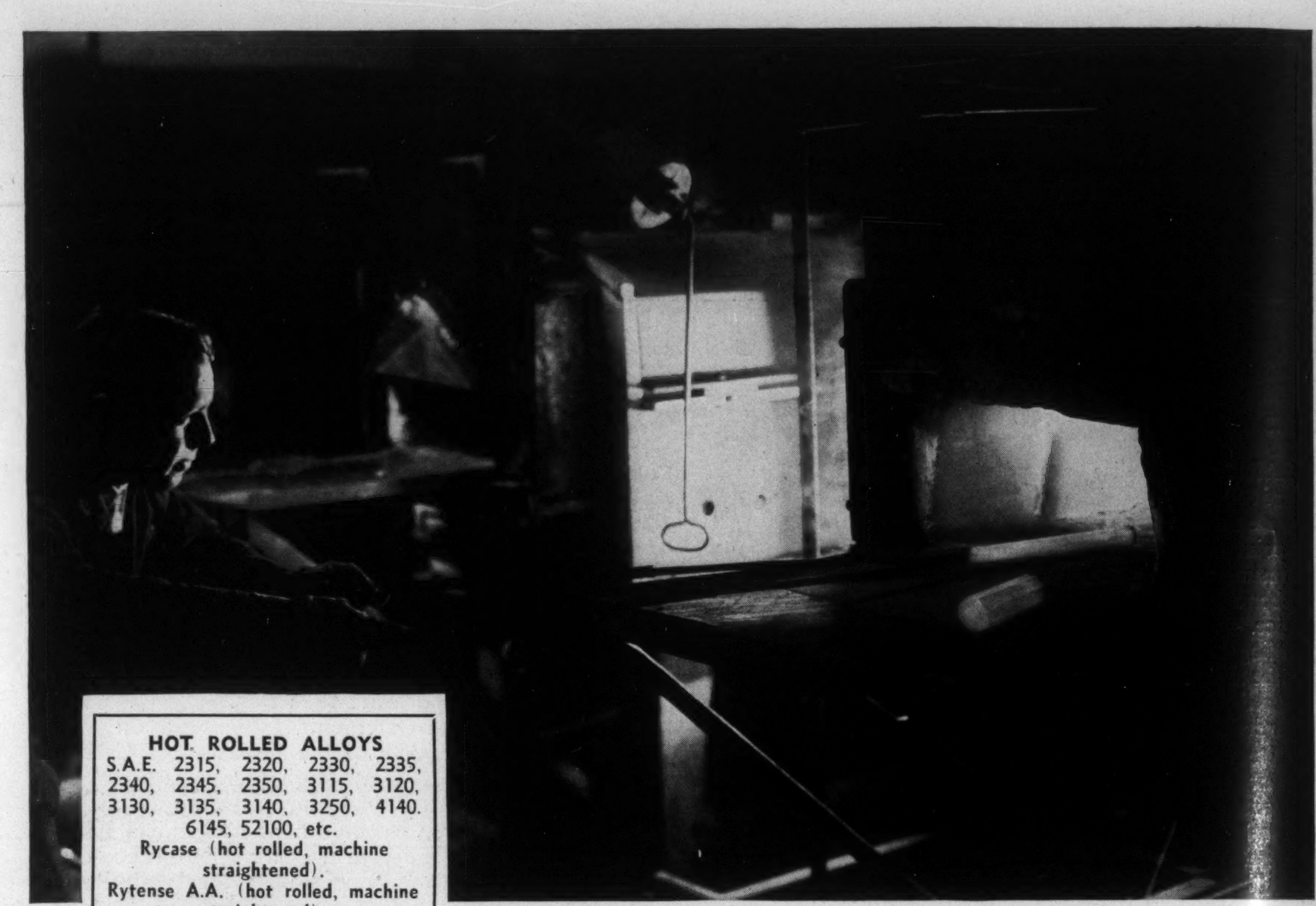

HOT ROLLED ALLOYS
S.A.E. 2315, 2320, 2330, 2335, 2340, 2345, 2350, 3115, 3120, 3130, 3135, 3140, 3250, 4140. 6145, 52100, etc.
Rycase (hot rolled, machine straightened).
Rytense A.A. (hot rolled, machine straightened).

COLD DRAWN ALLOYS
S.A.E. 2315, 2320, 2330, 3115, 3120, 3135, 3140, etc.

HEAT TREATED ALLOYS
Ryco (hot rolled, machine straightened).
Nikrome (hot rolled, cold drawn, machine straightened).
Ry-ax (hot rolled, machine straightened).
Ry-arm (hot rolled, machine straightened).

STAINLESS AND HEAT RESISTING ALLOYS
Allegheny Metal (Sheets, Bars, Welding Rod, etc.).

COLD FINISHED STEELS
Std. Shafting, Turned, Ground and Polished, Special Accuracy Stock, Rycase High Manganese Screw Stock, S.A.E. 1020, 1035, 1112, 1120, etc.

TOOL STEELS
Ryerson B.F.D. Die Steel
Ryerson "Shock" Steel
Ryerson V. D. Tool Steel
Ryerson High Speed Tool Steel

GENERAL STEEL PRODUCTS
All steel products such as Bars, Structurals, Plates, Sheets, Strip Steel, Welding Rods, Tubes, etc., are carried in stock for Immediate Shipment.

Ryerson Alloy Steels

A full range of special alloys, tool steels, stainless and heat resisting steels are immediately available through the Ryerson Steel-Service plants. Stocks include all major specifications.

Heat Treated Alloy Steels

The full value in alloy steels is secured after they have been heat treated to develop their greatest strength and toughness. We carry many sizes and types of heat treated alloy steel in stock, and also heat treat on order to any required specification. If you do not heat treat your own steel you will find this service helpful.

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RYERSON

Metallurgical Needs of the Glass Industry—I

By R. D. SMITH

Works Laboratory, Corning Glass Works, Corning, N. Y.

EVERY PIECE OF GLASSWARE, as delivered ready to use, represents the consumption of a certain amount of metal due to abrasion, oxidation, or heat checking. Each stage of glassmaking, from the handling of the raw materials to the final finishing operations on the ware, takes its toll of metal.

Two General Problems

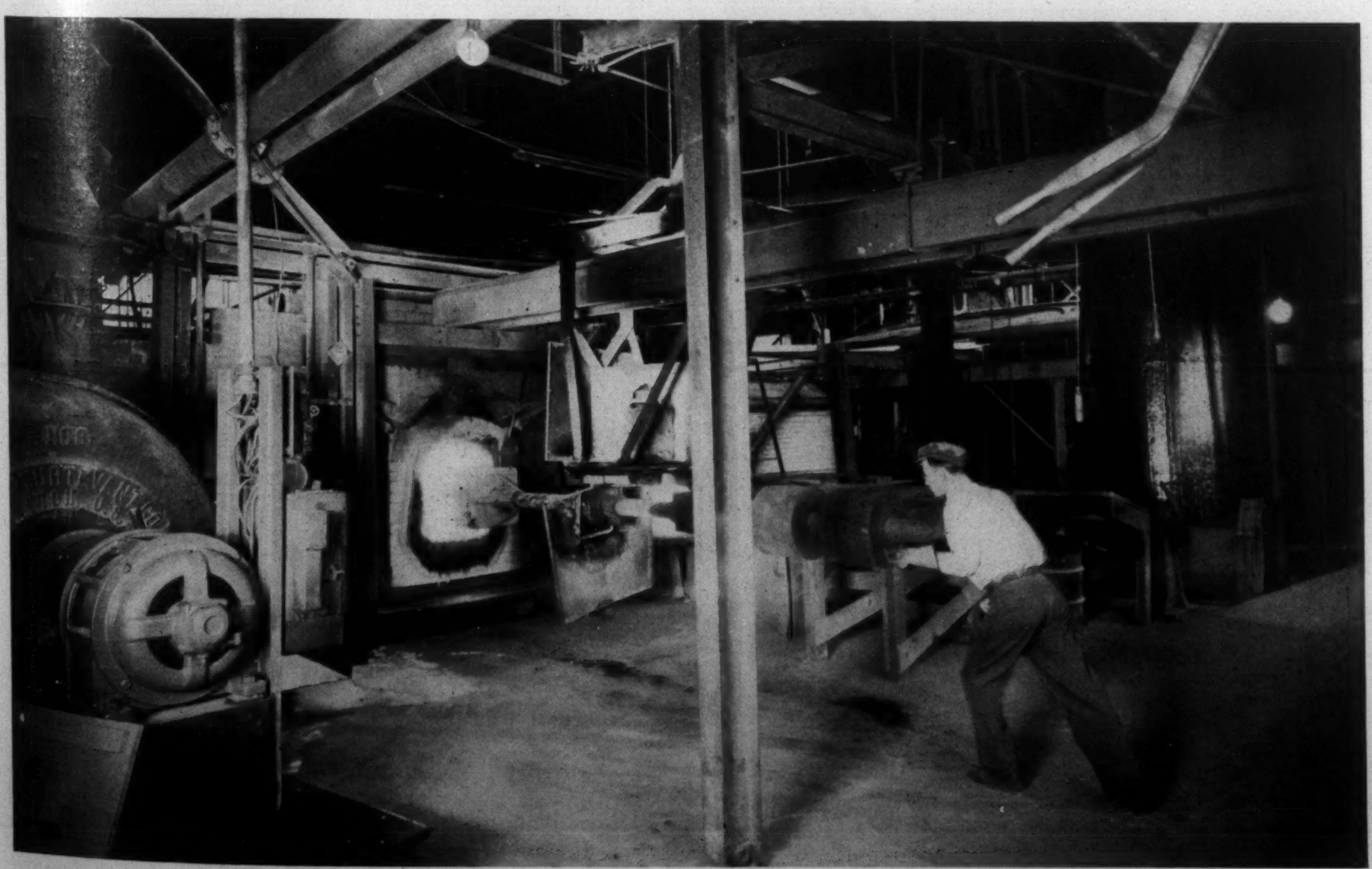
The problems relating to the consumption of metal in the glass industry naturally fall into two general groups.

The first group covers all of the servicing equipment problems relating to wear and abrasion in the handling of raw materials, the mixing and feeding of the batch, the oxidation and wear of the furnace parts and the grinding and finishing operations on the glassware.

The second group covers the parts used for handling and shaping of the molten glass through its plastic state into glassware.

The problems in the first group are quite similar throughout the glass industry, and many of the individual problems are found so frequently in other industries that equipment manufacturers are generally prepared to recommend and install the equipment built of those materials most satisfactory for the best service. The selection of the metals for construction of such equipment is usually dependent upon one or at most a relatively few physical properties.

One Method of Charging a Glass Tank.



Hand Gathering and Pressing of Lenses.

The second group presents to the glassmaker problems which he, rather than the equipment manufacturers, must solve. These problems not only differ in various branches of the glass industry but find no counterparts in other industries. The metal contact with the molten glass and hot shaped glassware brings into consideration properties of both metals and glasses which complicate the selection of the materials of which the metal parts are made. It will be the purpose of this paper to treat mainly with this latter use of metals and alloys.

A mere tabular presentation of the metals used in the glass industry would be of little value to the reader. This list to be complete would have to cover many of the commercial metals and alloys on the market and would fail to take into consideration the preferences of individual glassmakers for a particular composition for a certain use. Some description of the various glass handling and forming operations, as related to the properties of the metals and alloys, is considered necessary and will be given. Table I presents an outline of the stages in the manufacture of glass in which metals are used.

Table I.—Glass House Equipment

I. Handling Raw Materials, Batch and Cullet.
    Storage and mixing of batch materials, bins, scoops, conveyors, batch mixers, ventilating systems.
    Transporting and filling of mixed batch and cullet. Wagons, conveyors, hoppers, filling systems, filling scoops, batch pushers, hoods and ventilating systems, cullet crushers, and conveyors.
II. Melting Equipment.
    Fuel producers and carriers, burners and stack system, furnace buckstays, tie rods, water coolers, boot clamps, and furnace fittings.
III. Glass Working Machinery and Cooling Equipment.
    Machines, blowers and compressors, fire polishing.
IV. Hot Glass Transferring and Shaping Tools.
V. Lehring or Annealing Equipment.
    Lehr conveyors, pans, screens, and rolls.
VI. Finishing Equipment.
    Cutting and trimming.
    Grinding and polishing.
    Frosting, sand blasting, enameling.

The failure of the materials of construction of the batch mixing and handling equipment is mainly by abrasion. Where this wear is unusually severe, the mild ferrous sheet, plate and cast materials are displaced with higher carbon or alloyed steels. Cast (Z) metal for instance will give many times the life of cast or sheet iron buckets in conveyors. High manganese crusher jaws may be used for cullet crushing.

The iron contamination of the batch by the handling equipment is not a serious problem in the case of most commercial glasses. When special glasses are made, demanding almost complete freedom of iron oxide and other oxides of a deleterious nature, the use of such metal handling equipment is avoided. Pure aluminum may be used in this handling equipment, but wood is generally used, since the production of such special glasses is usually on such a small scale as to require little mechanical equipment.

The glass melting units are constructed of ceramic materials, supported on the outside by iron buckstays and tie rods. The common ferrous materials are suitable for these parts. Some of the boot burner nozzles and furnace parts exposed to higher temperatures, particularly around the glass working end of the furnace, may be required of calorized steel; high chrome, chrome-nickel, or nickel-chrome compositions. Chrome alloys of 13 to 28 per cent are used as well as the 18-8 and 25-20 per cent chrome-nickels. The 35-15, 60-15, and 80-20 per cent nickel-chrome alloys are used in the more severe types of service.

The glass forming machinery, exclusive of the hot glass handling parts, does not present problems unusual to machinery in general. It is true that the heat from the hot glass and molds frequently causes trouble due to expansion and poor alignment. This difficulty may be overcome by proper design and cooling of the machine parts. Fire polishing equipment frequently requires special alloys of the chrome or chrome-nickel type to withstand the intense heat and to avoid transferring a metallic oxide scale to the fire polished glassware.

The "lehr" (annealing oven) and lehr parts may frequently be made of the common ferrous materials when the temperatures do not exceed 550 deg. C. For higher temperatures alloy irons and steels are used in the important links of the conveyor system. The type of alloy used depends upon the temperature to which the metal parts are to be subjected. Some sheet glass manufacturers use chromium plated rolls in the lehrs.

The finishing operations on the glassware after annealing vary according to the type of ware. Bottles for instance may require no finishing operations unless an enameled label is to be applied in which event a kiln firing of the enamel is required.

Frequently, some cutting, grinding or polishing is done on the glassware as a finishing operation. In cutting glassware several methods may be employed in which metal tools are required. Cold glass may be cut by thermal shock using glowing resistance wires to produce locally heated lines on the glass surface followed by water contact to produce the fracture. Hot glass may be similarly fractured by a contact with a moist cold metal wheel. Thin steel wheels revolving at high speeds may cut glass tubing. Frequently cutting wheels are faced with stellite or similar alloys. Such tools merely start the fracture and are not generally used to cut through the glassware.

The grinding of plate glass is done with sand and other abrasives, revolving plates fitted with cast iron runners being used to back up the abrasive. There is considerable wear of the cast iron which is taken for granted since a material too hard and dense provides a poor backing for the abrasive.

Sand blasting supplies the problems peculiar to that type of equipment. Boron carbide nozzles and rubber stencils and hose will outwear the best metal parts in sand blasting equipment.

There are several finishing processes employing acids. In the etching of lines or designs onto glass, acid polishing and the frosting of glassware, equipment must be provided for solutions containing hydrofluoric acid, and for combinations of sulphuric and hydrofluoric acids. Chemical lead is used as the container for the above mixtures of acids employed in acid polishing. Dipping racks are made from Monel metal. Frosting equipment used to handle hydrofluoric solutions containing ammonium and sodium bifluorides may be built of lead, bronze or Monel metal. Monel metal resists the action of hydrofluoric acid extremely well. Rubber lined iron containers are suitable for the dilute hydrofluoric acid solutions when not heated over 170 deg. F. Iron drums have practically displaced the old lead carboys as shipping containers for hydrofluoric acid since the iron may be so treated as to be passive toward this acid of strength over 60 per cent.

The hot glass transferring and shaping methods and devices may be classified as follows:

Transferring and Shaping Molten Glass:

- Hand Gather:
  - Blow pipe
  - Punty-shears
  - Ladled
- Flowed:
  - Poured from pot
  - Rolled—plain, wire and figured
  - Tubing and cane
  - Corning ribbon flow bulb machine
- Drawn:
  - Vertical drawing of tubing
  - Vertical window glass cylinders
  - Fourcault process
  - Colburn process
- Mechanical Gather:
  - Suction — Owens and Westlake machines
  - Gob feeder—Hartford-Empire types
- Mold Shaping:
  - Blow molds
  - Press molds

Transferring Hot Glass to the Shaping Device

The transfer of the hot glass from the furnace employs metal tools in many cases. Hand "gathering" of glass is still done in many plants. The two most common methods of hand "gathering" are: By use of a blow iron for hollow blown ware, and by a "punty" iron for ware of the solid or pressed type.

The blow iron shaft is made from seamless steel tubing with a shank of steel welded thereon and the iron tip or nose in turn welded to the shank. Various metals are used for the tip which must be replaced from time to time, the so-called "cold rolled steel" being most frequently used. The tip may be chrome plated to eliminate the metallic oxide from the "moil" or ("chest cullet") which is readily removed from the iron blow pipe after the glassware is blown and cracked off. Since all of the chest cullet is valuable as a batch addition and such cullet is usually required to be low in iron content, chromium plating is very desirable.

On the other hand the pronounced tendency for glass to adhere to stainless steels is an advantage in drawing rather large or valuable drafts of glass, such as in the vertical drawing of thermometer tubing where the blow iron with the "gather" is mechanically drawn up an elevator shaft. The glass must not break loose from the iron and fall down the shaft and the adherence of glass to metal should be at its best. The removal of the glass from such irons is rather difficult and time consuming so that rapid gathering of glass for small ware is performed better with chromium plated irons from which the moil is stripped rather easily.

"Punty" irons are usually a rod of metal about ½ in. in diameter and 40 to 50 in. in length, provided with a wooden handle on one end and a fired clay ball on the other. The glass is gathered on the clay ball and the punty held over the mold into which the glass is allowed to flow, the presser cutting through the glass stream with hand shears. These irons must be as light and strong as possible and must not oxidize or scale. It is important that the irons remain straight under the temperature and load conditions of the glass transfer. The high nickel-chrome iron alloys appear to be superior to the straight chrome iron alloys in resistance toward bending. The breaking off of any of these tools in the furnace or pot entrance results in the loss of the glass for a considerable period of time because of reactions forming gas.

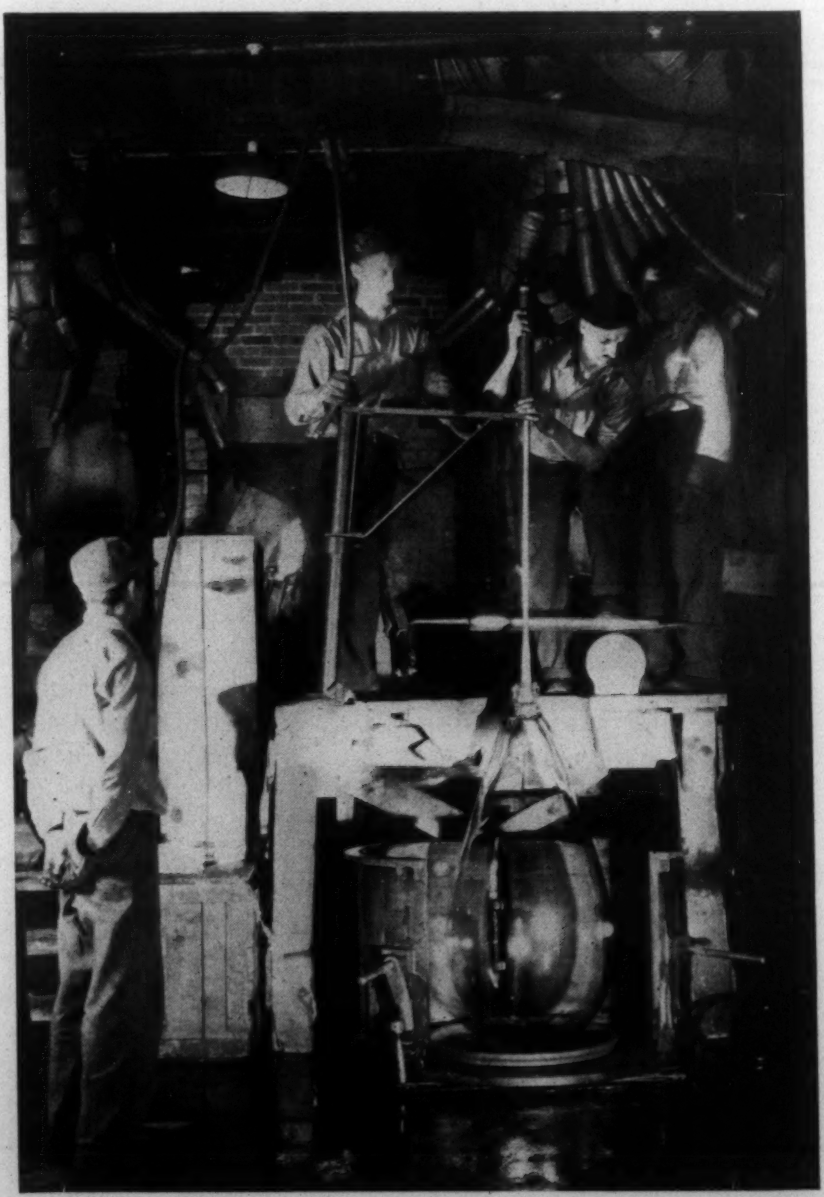
Other tools such as tube punties are frequently made from nickel-chrome alloys of the 35-15 per cent type although there may be a preference for 60-15 per cent or the 80-20 per cent compositions in more severe uses in which high temperature strength is important.

Glass may be ladled out of the working end of the glass furnace in cast steel ladles. The ladles are prechilled in water and the "skull" or chilled glass layer left in the ladle after pouring is subsequently removed and returned to the melting end of the furnace or glass tank. Some glassmakers prefer a chrome-nickel-iron alloy ladle of the 25-20 per cent type.

Should the ladled glass be used in making plate glass by the old process, the glass rolls are the next consideration. Since plate glass is ground and polished the rolls may be made of cast iron or steel.

In the case of continuous rolled glass and, in par-

Hand Blowing of Large Glass Tub.



ticular, figured rolled glass, such as is made on the Boudin machine, the composition of the rolls is important. The bottom roll containing the figured pattern may be cast iron, ordinary steel or nitrided nitralloy. The top roll giving the smoother glass surface which is not subsequently polished must be of either high chrome or high nickel-chrome alloy. The rolls are water cooled and it is impossible to obtain a smooth top glass surface with top rolls of high thermal conductivity materials; hence alloy steels of low thermal conductivity do not give the objectionable chill wrinkled top glass surface.

It is apparently the low rate of thermal conductivity which is necessary in obtaining a good rolled glass surface, since regulations of the wall thickness and amount of cooling fails to make a regular steel roll satisfactory. The alloy steel roll also resists heat checking better than the mild steel or cast iron rolls. In making wire glass the mild steel wire mesh is fed into the glass stream in a continuous manner as the molten glass is being drawn through the rolls. Chromium plating of the wire is sometimes performed before use in the glass. Such plated wire mesh produces less gas or seed in the glass and gives a clearer product.

In glass feeding devices where the glass flows through an orifice, it is sometimes desirable that ceramic materials be avoided since the latter substances gradually dissolve in the glass and controlled orifice size is difficult to maintain. Platinum, or platinum alloys, are sometimes used in these parts where refractory corrosion is severe.

Tube drawing machines of the Danner and Vello types use metal mandrels and bowls from which the glass is drawn in a continuous manner. Since the glass temperatures in these cases fall in the working range of glass (usually below 1000 deg. C), it is possible to use nickel-chromium alloys of the 80-20 per cent type.

The general difficulty in the use of metals in hot glass, where dependence is placed upon a protective oxide coating on the metal, is that the glass is both an oxide former and a flux for the oxide at high temperatures. Two serious difficulties arise upon dropping metallic objects into molten glass. A colored glass or "spew" arises from the metal and numerous bubbles or "seeds" develop in the glass.

The formation of "seeds" or bubbles in glass, due to contact with immersed metals, depends to some extent upon the composition of the metal. Nickel causes an excessive amount of "seed" while chromium appears to be less offensive in this respect. The nickel-chrome alloys are improved by the chromium content and may be chromium plated with further improvement. High chrome-iron and chrome-aluminum-iron alloys are excellent in respect to the low amount of "seeds" and blisters formed in glass. It is thus observed that, while metals are very objectionable in the melting and refining of glasses, nevertheless the glassmaker uses metals for particular purposes in some of the glass flowing and drawing devices.

The Corning Bulb Machine[1] uses a continuous glass stream, which is rolled between an upper pocket roll and a lower smooth roll in order to distribute the glass in the ribbon to the best advantage for subsequent glass forming operations. The rolls are of gray cast iron and are water cooled. Very little heat is removed from the glass stream by the rolls and the ribbon of glass is now fed onto a series of orifice plates so that the glass humps or buttons in the ribbon are indexed over the holes of the orifice plates. A blow head now descends upon the button of glass forcing it through the hole in the orifice plate and admitting the proper puff of air for proper elongation of the blank of glass. The two sides of the mold close around the glass blank and the final blowing operation is performed.

Since the molds are coated with a layer of linseed oil and carbonized cork, which during the machine operation has been previously saturated with water, a relative rotation of mold and glass blank is possible. The generation of steam from the paste mold surface facilitates cooling of the glass and produces good glass finish, no mold seams being in evidence on the finished blown ware. The blow head seats onto the sharp edge of the orifice in the plate thus reducing the holding edge of the bulb to the minimum; a slight tap removes the ware from the ribbon and delivers the bulb onto the annealing conveyor.

The orifice plates are made from nitralloy and are nitrided since extreme hardness and retention of sharp orifice openings is required.

The blow head tips are made from a high tungsten steel and are chromium plated to offset the sticking tendency of the glass. It is found that plated tips eliminate the difficulty with partially closed bulb openings in that the glass blows free from the entire face of the tip while unplated blow tips give difficulty in this respect. Such a partially closed bulb opening causes difficulty in the assembly of the lamp at the lamp factory.

Another type of feed, peculiar to the Owens bottle and the Westlake bulb machines, sucks up the glass gather from a forehearth into the parison cups by means of reciprocating rams. The shearing off of the glass tail, after the gather has been made from the pool of molten glass, requires certain resistance to wear in the metal parts. Nickel-chrome cast irons find use in such parts as well as high speed steel inserts.

"Gob" feeds of the Hartford-Empire type shear off the glass stream which exudes from an orifice in the forehearth. A ceramic needle partially submerged in the molten glass operates so that its upward and downward movement in the glass over the lower orifice opening assists in the control and formation of the "gob." The shears for cutting off the glass are synchronized with the needle action and the glass machine so that, as the stream of glass is severed, the upward motion of the needle pulls back the end of the stream, while the "gob" falls into the receiving mold, usually directed by a system of troughs. The shears, which are kept cool by a water spray are either of high speed steel or are faced with stellite. The trough may be made of cast iron or steel since a wax or oil together with water is used on the trough surface to form a lubricant or steam cushion for the hot glass. Since the shear action is extremely rapid, the reciprocating parts are made of Dow metal so far as possible to reduce the inertia.

(To be continued)

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A Self-Recording Apparatus

For Thermal Analyses

By R. L. WILCOX and J. R. BOSSARD

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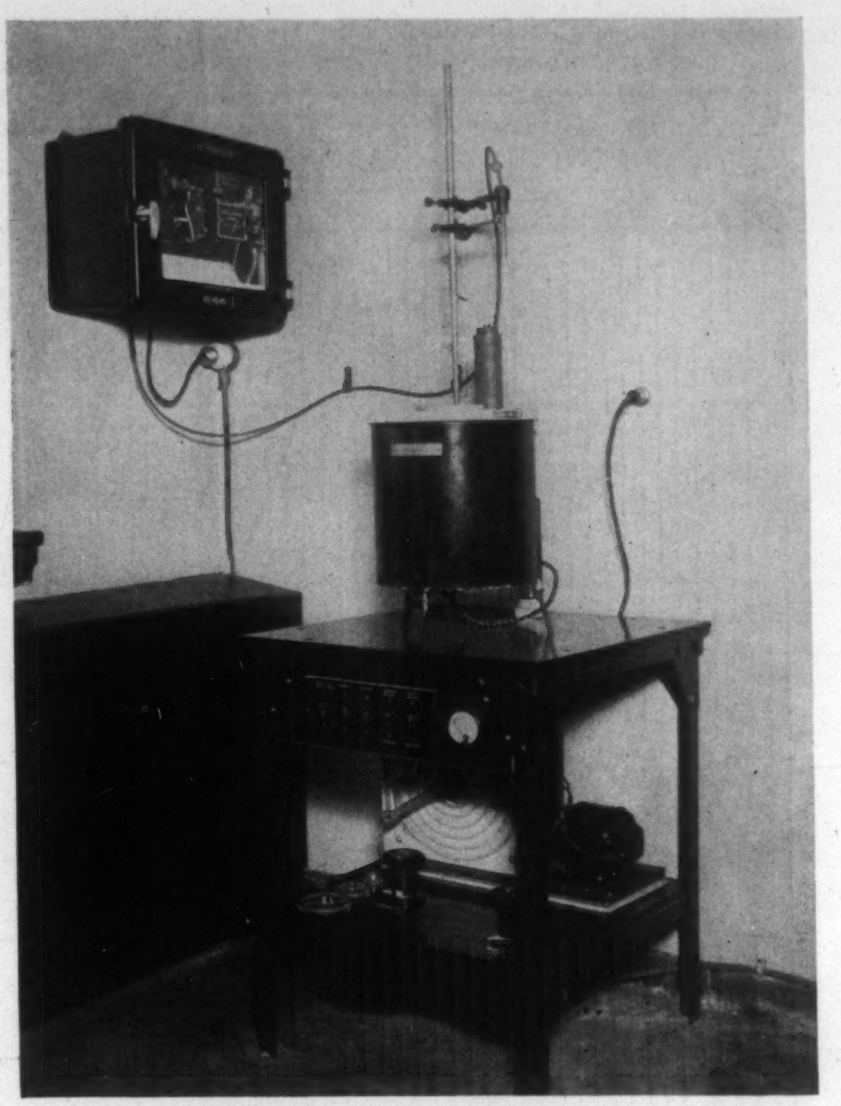


Fig. 1. Self-Recording Thermal Analysis Apparatus.

THERMAL ANALYSES of metals and alloys by the determination of heating and cooling curves are important from both practical and theoretical considerations. Practically, they are of value in determining melting points and heat treatment information. In fundamental studies, they are of importance in determining solidus, liquidus, reaction, and transformation temperatures in the development of phase diagrams.

The actual determination of a cooling or heating curve by any other than a self-recording apparatus requires the entire attention of an operator over a considerable period of time. A satisfactory apparatus for general alloy development work and preliminary theoretical investigation is one in which a minimum of attention is required, the cooling and heating rates can be controlled at a chosen and reasonably uniform rate, and the data are automatically recorded in finished form with a fair degree of accuracy. An apparatus, Fig. 1, embodying these features has been designed and constructed at the research laboratory of The New Jersey Zinc Co. It has proved so useful for work in which a sensitivity of ± 1 deg. C. is sufficient that others making such determinations may be interested in its construction and application. (This apparatus is not intended to replace precision equipment already in common use, nor has any provision been made for the development of differential rate curves.) A typical example of the results obtainable is shown by the cooling curve in Fig. 2.

The apparatus may be considered as being composed of a number of individual units. The design, use, and operation of each unit are described separately.

The Furnace and Its Control

The furnace is of the simple resistance type. The main features of the design are ample insulation and a graded winding to give a constant temperature area in the working zone.

The 4 in. diameter refractory tube is wound with 90 ft. of No. 18 Nichrome V wire and can be operated on either a 110 or 220-volt circuit. The furnace draws a maximum of 6 amp. at 220 volts and is capable of reaching 1000 deg. C. A sketch of the furnace and its wiring scheme is shown in Fig. 3.

The temperature of the furnace is controlled by three rheostats:

1. An adjustable rheostat in series with the furnace for the control of maximum amperage.
2. A special spiral rheostat in series with the furnace to control rates of heating and cooling.
3. An adjustable rheostat to shunt the spiral rheostat for control of minimum amperage during heating.

A wiring diagram of the furnace control is shown in Fig. 4.

The adjustment and use of the three rheostats depends upon whether a cooling or a heating curve is to be determined and the specific temperature interval desired.

The Spiral Rheostat

In heating or cooling curve determinations it is desirable that the heating or cooling rate be such that a plot of temperature against elapsed time gives as nearly a straight line as possible so that any change in slope will indicate a phase reaction. Heating and cooling rates are controlled by the specially designed spiral rheostat which is used in conjunction with the two auxiliary rheostats. The spiral resistance (Fig. 5) consists of a molded carborundum plate with grooves in the form of an Archimedes spiral into which the resistance element is cemented. The latter consists of 170 ft. of No. 17 Nichrome V wire wound on a ¼-in. mandrel. The spiral element has a total resistance of 55 ohms. A motor-driven contact arm rides on the surface of the resistance coil. A connection is made from this contact to another one riding on a brass ring in the center of the carborundum plate. Electrical insulation of the moving contact from the framework is provided by a Lavite tip on the contact arm.

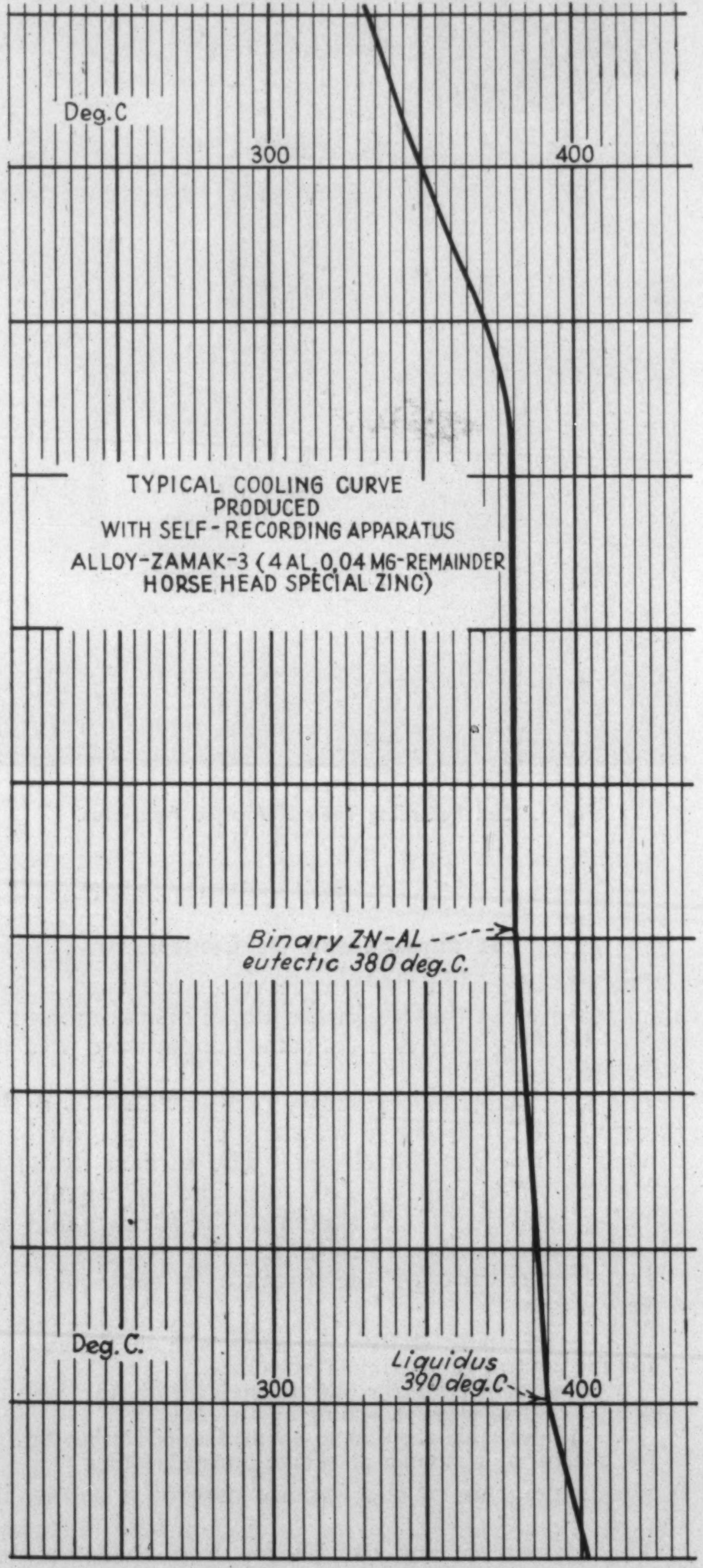


Fig. 2. Typical Cooling Curve of Results Obtainable. (Reduced about one-third).

The mechanism for driving the contact arm is shown in Fig. 6. A 1/20 horsepower, 1800 r.p.m., reversible induction motor furnishes the drive through a 900 to 1 ratio gear reducer. The motor and gear reducer are mounted on a separate sliding base, making it possible to use worm gears of different sizes as well as to manually adjust the contact arm. Four different sizes of worm gears are used interchangeably to control the speed of the contact arm around the spiral. The rates obtained are from 1 to 3 hrs. for a complete cycle. The rate of travel around the spiral controls the heating or cooling rate. Rates of about ½ to 2 deg. C. per min. are obtained. Examples of controlled rates obtained with the spiral rheostat are shown in Fig. 7.

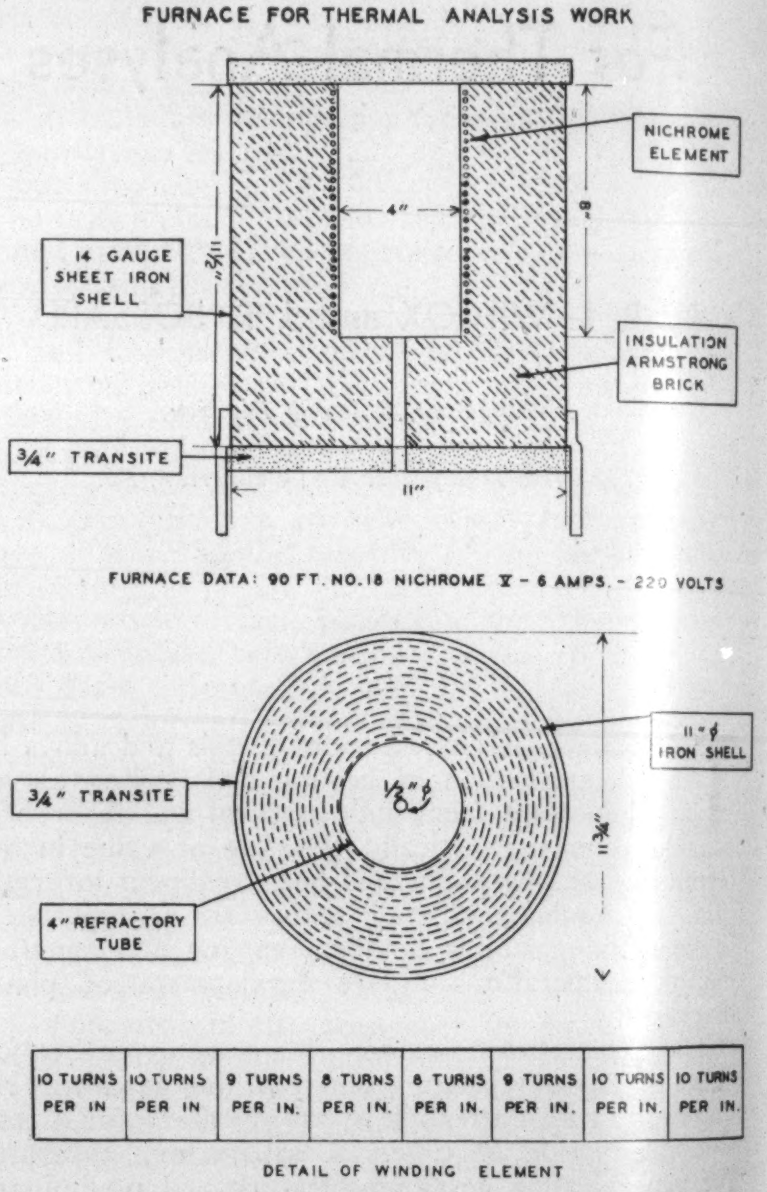

FURNACE FOR THERMAL ANALYSIS WORK
NICHROME ELEMENT
4"
8"
11½"
14 GAUGE SHEET IRON SHELL
INSULATION ARMSTRONG BRICK
¾" TRANSITE
11"
FURNACE DATA: 90 FT. NO. 18 NICHROME V - 6 AMPS. - 220 VOLTS
11" ϕ IRON SHELL
¾" TRANSITE
½" ϕ
11¾"
4" REFRACTORY TUBE
10 TURNS PER IN
10 TURNS PER IN
9 TURNS PER IN.
8 TURNS PER IN.
8 TURNS PER IN.
9 TURNS PER IN.
10 TURNS PER IN.
10 TURNS PER IN.
DETAIL OF WINDING ELEMENT

Fig. 3. Sketch of the Furnace and Its Wiring.

The gear train shown in Fig. 6 operates a normally closed Burgess microswitch which acts as a limit switch, stopping the motor when the contact arm reaches the end of the spiral. The limit switch functions with the motor running in either direction.

Cooling Curves

To make a cooling curve determination, the movable contact arm on the spiral rheostat is set at the center of the spiral. The shunt switch is set for "cooling" which disconnects the shunt rheostat. The spiral rheostat short-circuiting switch is thrown "off" and the furnace switch thrown "on." The series resistance is adjusted to give the desired initial amperage and the furnace allowed to come to the proper temperature. The proper gear to give the intended cooling rate is placed in the driving mechanism. The motor reversing switch

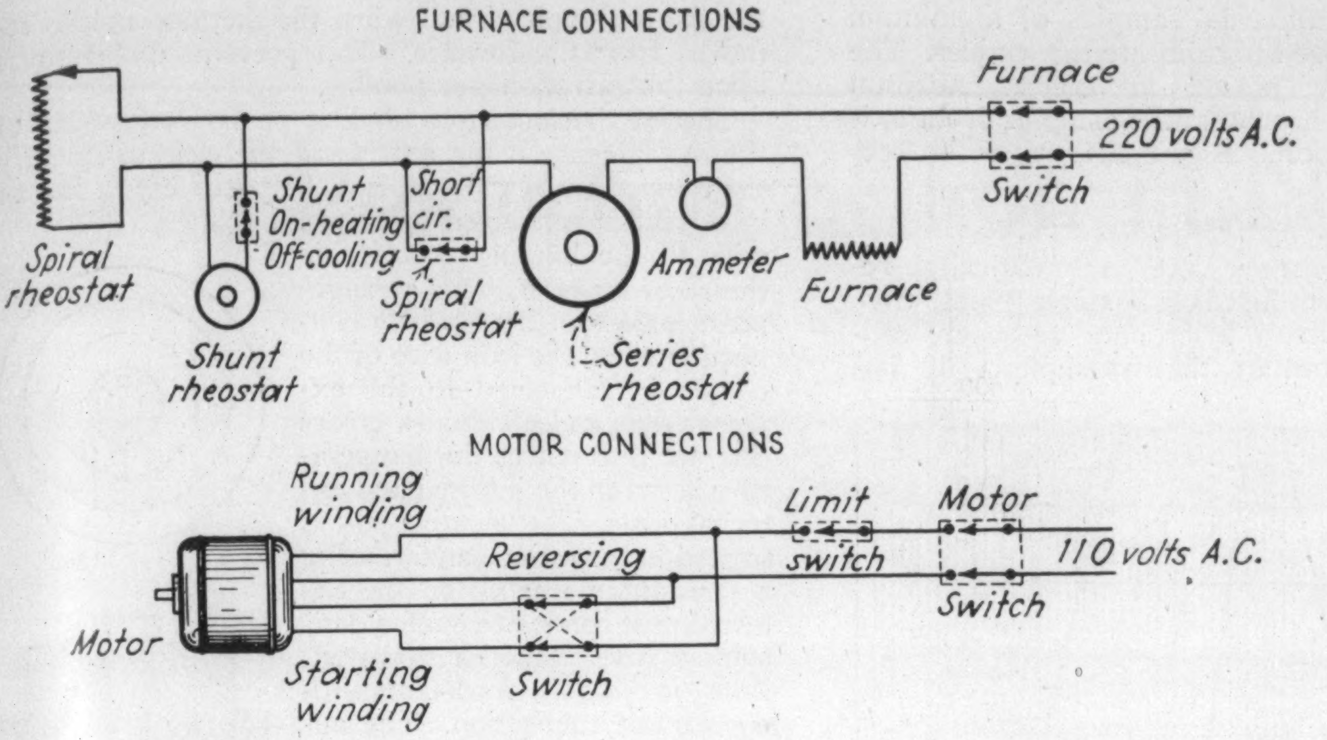


Fig. 4. Wiring Diagram of the Furnace Control.

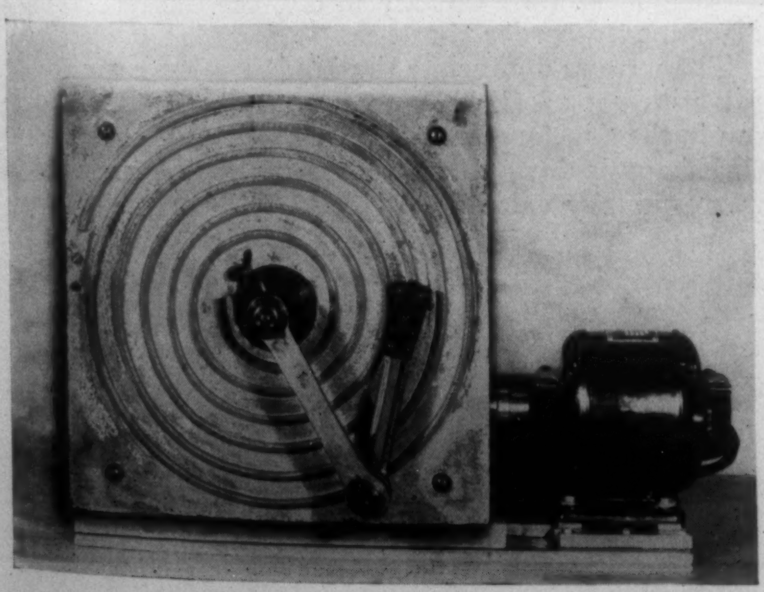
is set to "cooling." The furnace cooling cycle is started by throwing the motor switch "on." The limit switch automatically stops the motor when the outside of the spiral is reached. Cooling to lower temperatures is accomplished by returning the contact arm to the center of the spiral and adjusting the series resistance to give the same value as obtained at the end of the previous cycle.

No provision was made for reducing the furnace current to zero while using the spiral rheostat control. Such provision would be of no value in the work for which the equipment was designed since cooling curves at low temperatures are not useful on the materials investigated.

Heating Curves

To make a heating curve determination, the contact arm of the spiral rheostat is moved to the outside and the furnace switch thrown "on." The spiral and shunt resistances are short-circuited and the series resistance adjusted to give the maximum amperage desired. The shunt switch is set to "heating." The spiral and shunt resistance are again connected in the circuit and the shunt resistance adjusted to give the minimum amperage desired. The amperage readings will then correspond to the maximum and minimum of the range wanted. The proper gear to give the intended heating rate is placed in the driving mechanism. The motor-reversing switch is set to "heating" and the furnace heating cycle started by throwing the motor switch "on." The limit switch automatically stops the motor when the center of the spiral is reached. If heating cycles are wanted over a wide range, it is necessary to make readjustments as for cooling determinations.

Fig. 5. Front View of the Special Rheostat.



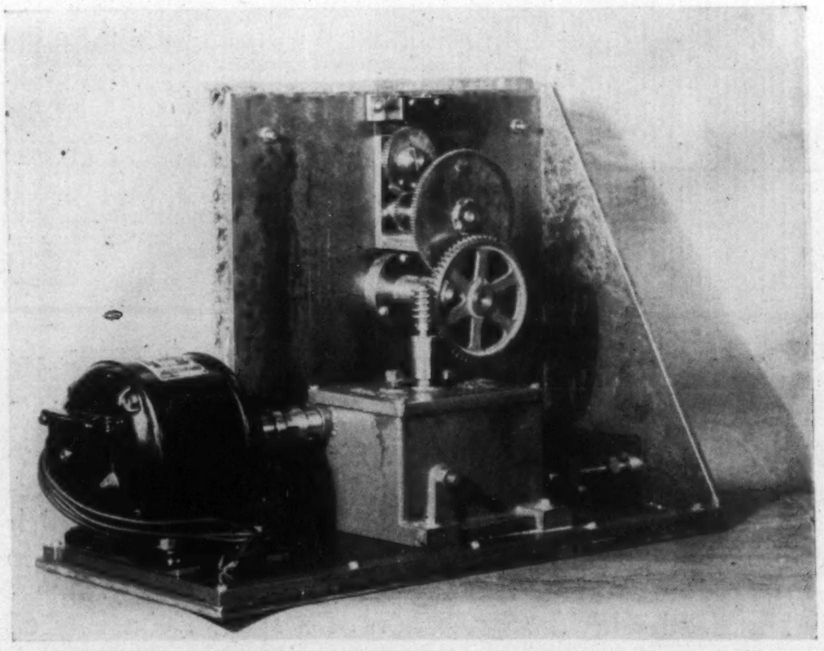


Fig. 6. Rear View of the Spiral Rheostat Showing Driving Mechanism.

Thermocouples

A thermocouple is used to determine the temperature of the metal or alloy during heating or cooling. This is made from Leeds & Northrup iron-constantan No. 20 B. & S. gage bare wires, separately insulated with cotton sleeving and enclosed in a flexible copper tube. The end of the couple which is immersed in the liquid melt is protected by a Pyrex or silica tube. The portion of the thermocouple enclosed in the protecting tube is insulated with porcelain tubing.

A special clamping device is used to hold the thermocouple in a rigid position and to facilitate lowering or raising the thermocouple into or from the melt. This arrangement can be seen in Fig. 1. The thermocouple is connected to special binding posts on the outside of the recorder. A special arrangement is also embodied in the thermocouple clamping device which enables a convenient change of the Pyrex or silica protecting tubes.

U. S. Bureau of Standards' samples of aluminum, zinc, lead, and tin are used to calibrate the couples. The standard samples are placed in special Acheson graphite crucibles which protect the samples from oxidation and contamination. Fig. 8 illustrates the special crucible.

Recorder

Temperature-time curves are automatically recorded. The instrument used is a single point, two-range, Leeds & Northrup Micromax recorder, calibrated for iron constantan thermocouples. It has automatic reference junction compensation so that no separate reference junction need be maintained. Current standardization is automatic every 45 min. which eliminates possible errors resulting from failure to standardize the potentiometer current. The instrument is standard with the exception of a special chart speed and the two-range feature.

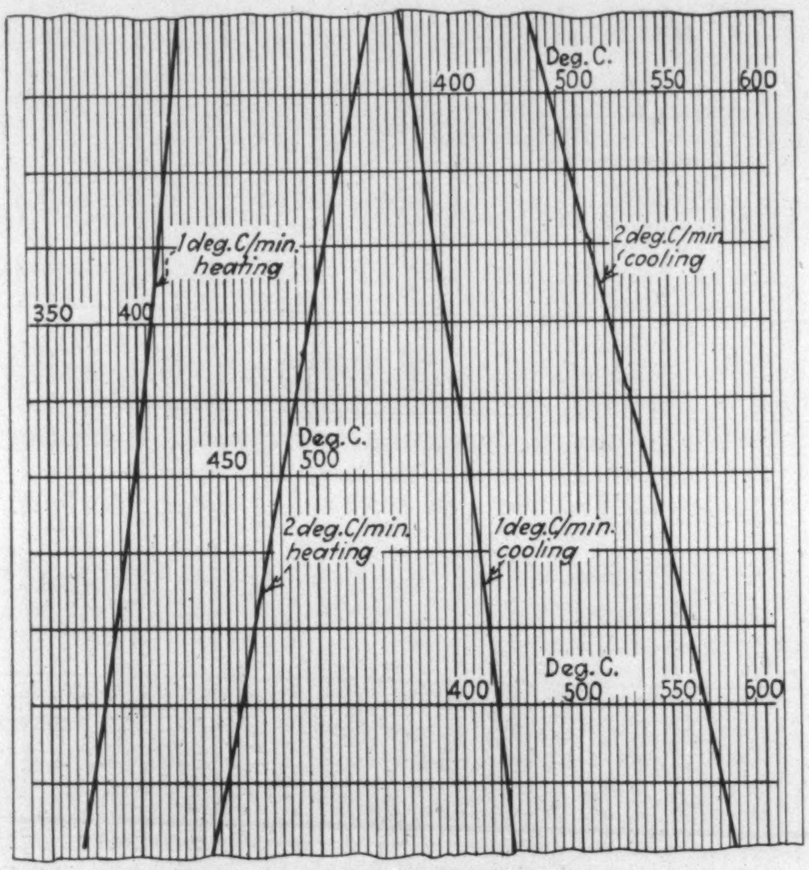


Fig. 7. Examples of Controlled Rates of Heating and Cooling Obtained with the Spiral Rheostat.

The double range permits thermal analyses from 0 to 500 deg. C. and from 300 to 700 deg. C. by a simple switch arrangement. The chart temperature is printed in 5 deg. C. divisions and can easily be estimated to within ± 1 deg. C. The chart speed is 12 in. per hr. which yields a curve of proper slope for legibility. The correct chart must, of course, be installed when the range is changed.

The balancing mechanism operates at 30 r.p.m. which gives 30 adjustments per minute on the potentiometer circuit. A separate switch was installed to open the thermocouple circuit when the thermocouple is removed from the furnace. This prevents undue stress upon the galvanometer pointer.

Special thermocouple binding posts were added to the instrument on the outside of the case to simplify the connection of the couple. The positive post has an iron washer connected with iron wire to the binding post inside the recorder case. This arrangement makes an iron-to-iron connection when the iron wire of the couple is connected to the external post and eliminates errors due to differences in temperature between the internal and external posts. The negative post is treated in the same manner, using a constantan washer on the external post connected with a constantan wire to the internal post, thus making a constantan-to-constantan connection. The automatic reference junction compensating coil is placed near the internal posts where it compensates for changes in temperature at this point.

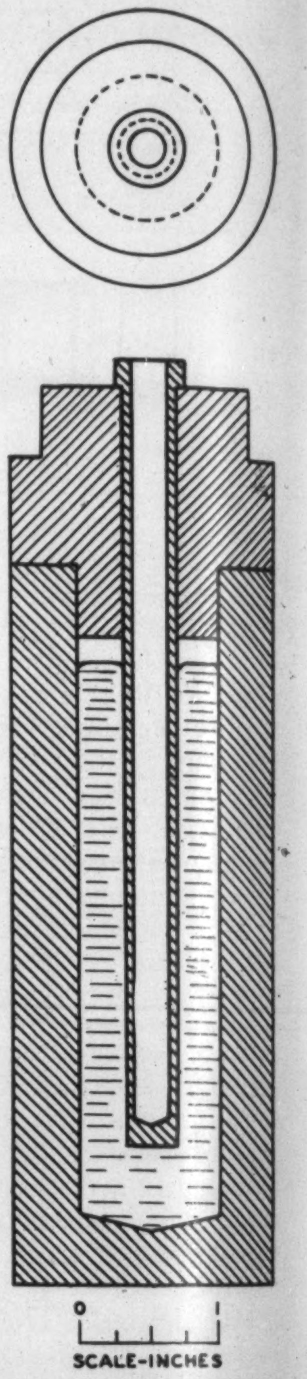


Fig. 8. Special Graphite Crucible for Standard Samples.

Summary

A self-recording apparatus for thermal analyses to be used in alloy development work and preliminary theoretical investigations has been designed and constructed. A sensitivity of ± 1 deg. C. has been obtained with heating or cooling rates adjustable at about ½ to 2 deg. C. per min.

The apparatus has a Nichrome heated furnace with the winding arranged to maintain a constant temperature area in the working zone. Three rheostats regulate the heating or cooling current. One of these is a motor-driven, spiral rheostat by means of which the temperature is either raised or lowered through the selected range at a predetermined rate. The temperature is measured by means of an iron-constantan couple and is recorded as a function of time directly in degrees centigrade on a Micromax recorder chart.

The writers appreciate the kind assistance and helpful criticism of C. F. Homewood and E. A. Anderson in the development of the apparatus. Counsel with G. Edmunds during the preparation of the manuscript was especially valuable.

The Production of Iron in Norway

Modern Progress in Electric Smelting

By HERMAN CHRISTIANSEN

Oslo, Norway

IN THE YEAR 1260 B. C., the Hittite King, Chattusil II, of Asia Minor, wrote to his son-in-law, Ramses II of Egypt:

> "With regard to pure iron, about which you write to me, there is at present no pure iron in my store at Kisvadna. The present time is not auspicious for making iron, but I have written about making pure iron. It is not yet ready; as soon as it is ready, I shall send it to you. I send you hereby only a sword blade of iron."

In other words, iron was at that time in practical use for weapons in Asia Minor, but not yet available to the nearest civilized peoples. Gradually the knowledge of this production found its way northwards. About the year 1000 it had reached Central Europe and about the year 500 B. C. it came north.

Quite naturally, the iron there, as everywhere else, was for a long time looked upon as a fine and costly material to be used only for weapons. Many hundreds of years elapsed before it asserted itself as a new and exceedingly helpful material in agriculture, in the handicrafts and in all work. About the year 700 A. D. this development had reached its height, and thus there was introduced the greatest epoch in the history of Norway, the Age of the Vikings, lasting up to the flourishing period of the Middle Ages in the thirteenth century.

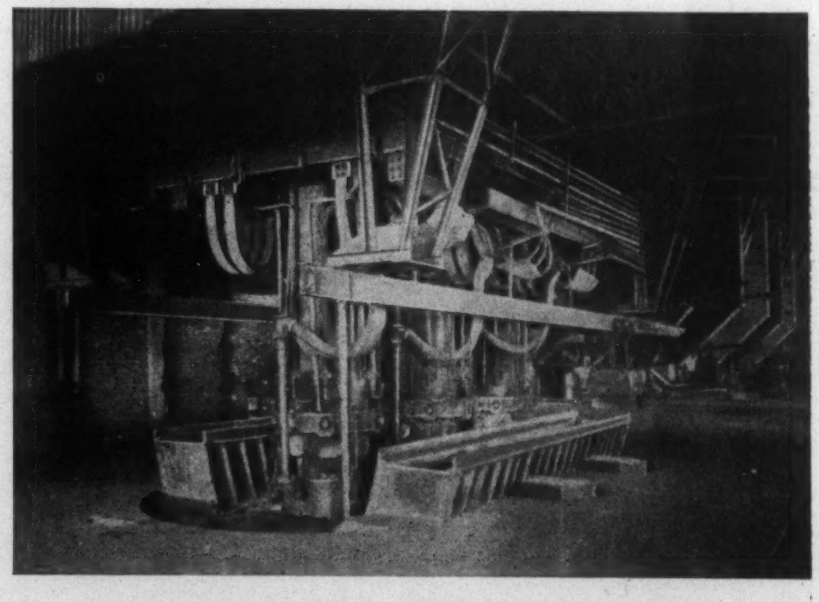
Bog Ore an Early Source of Iron

It was from bog ore that the iron was made in ancient times and in the Middle Ages. Some attempts at mining were made around 1500 A. D. but it was not until the beginning of the seventeenth century that mining reached any importance. Bog ore consists of iron compounds washed out in the boggy soil and concentrated in the stagnant water and thereafter reduced to solid form as small lumps beneath the turf. Almost up to the present time, bog ore has been used for making iron in the country districts in Norway.

The actual iron production was in the olden days a home industry—a part of the peasant's regular farm work to satisfy his own or local requirements—and it was generally carried on in the autumn when the work in the fields was finished. As a source of heat, good dry wood was needed, preferably mixed with a little charcoal.

An Ancient Furnace

The "furnace" was not built up with masonry; it was dug down in the earth like a funnel-shaped hollow, at the top perhaps one meter in diameter, at the bottom as a rule only 20 to 30 centimeters. The hollow was lined with small slabs and then coated with a thick layer of clay, making it appear like a deep kettle. The bellows were fastened in such a way that they inclined towards each other on both sides of the hollow. The pipe through which the air was to be blown was slightly cone-shaped in towards the kettle. When the kettle was half-filled with glowing charcoal, the dried and crushed ore was put in. It was put in in layers, alternately one layer of ore and one layer of charcoal. Then the blowing began by means of the bellows, the furnace mass sintered together and the iron was separated, the slag tapped away, and the iron was left in the kettle and taken out with tongs or a hook.



General View of Top of a Spigerverk Electric Blast Furnace in Norway.

The iron produced in this way was a soft wrought iron, of rather uneven quality, but very well suited for certain purposes. No doubt a steadily increased and extended use of iron in daily life has gone hand in hand with the increased production of iron. This was an exceedingly important factor in the economic life of Norway during the Viking Period and the Middle Ages. Norway was at that time self-sustaining with regard to iron, and perhaps more than that. With the increasing consumption, bog iron was not only made for home use on the farms, but iron smelting was also carried on on a big scale by people who made it their livelihood.

During Norway's period of decline in the Middle Ages, in particular in the fourteenth and fifteenth centuries, the entire Norwegian social life passed through radical changes. Foreign money power obtained a dominating influence over the economic life of the country, so that many of the national values disappeared or remained latent. So also the old iron production. The towns received their iron from abroad, and the bog iron became reduced to only farm production for one's own requirements in the country districts.

However, in the sixteenth century there began to dawn again an interest in Norwegian iron, at the same time that the mining industry was introduced from the south. During the period of the Renaissance, all of the governments in Europe endeavored to exploit their national resources. The mining of metals was quite naturally the most conspicuous source of wealth.

This movement did not break through in Norway until the beginning of the seventeenth century. The government strongly encouraged the seeking of ore deposits and the erection of smelting works. Through government favors, each works obtained a certain area of the surrounding forest, from which it was entitled to obtain a supply of charcoal. The ore was smelted in blast furnaces, and the products were partly castings and partly wrought iron in rods.

Charcoal Blast Furnaces

The time intervening between 1600 and 1850 A. D. represented the noontide of the charcoal blast furnaces in Norway. Seventeen iron works—all of them rather small—with 23 blast furnaces produced an especially high quality iron. The total Norwegian production of pig iron during these two and a half centuries amounted to about 1,333,000 tons, corresponding to an average of 5000 tons a year. (For comparison: The world's steel production before the Wars of Napoleon was only a few tens of thousands of tons per annum.) A large part of this was exported, and even today "Norway Iron" is used as the designation for a pure, soft iron. As only a few thousand tons were exported annually, it was its quality that made the Norwegian iron known. But no doubt Swedish iron also enjoyed the same designation in the olden days.

Sweden's iron industry has been highly developed and has played an important part as a supplier of iron to the rest of the world, in particular during the period of 1500 to 1870 A. D. And even now iron and steel production occupies a dominating place in the industry of Sweden. The designation, "Norway Iron," had undoubtedly been retained for all of the Swedish iron, after Norway in about 1850 had been eliminated as a competitor.

The majority of the Norwegian iron works were situated in the forest abounding districts in the eastern part of the country, where the iron ore was found in the vicinity. In the winter time the charcoal was hauled from the forests on the snow, as was also the ore from the mines near Arendal, around Christiania (now Oslo), by Lake Mjösen and near Kongsvinger. The large and important deposits in the northern part of Norway were not known at that time.

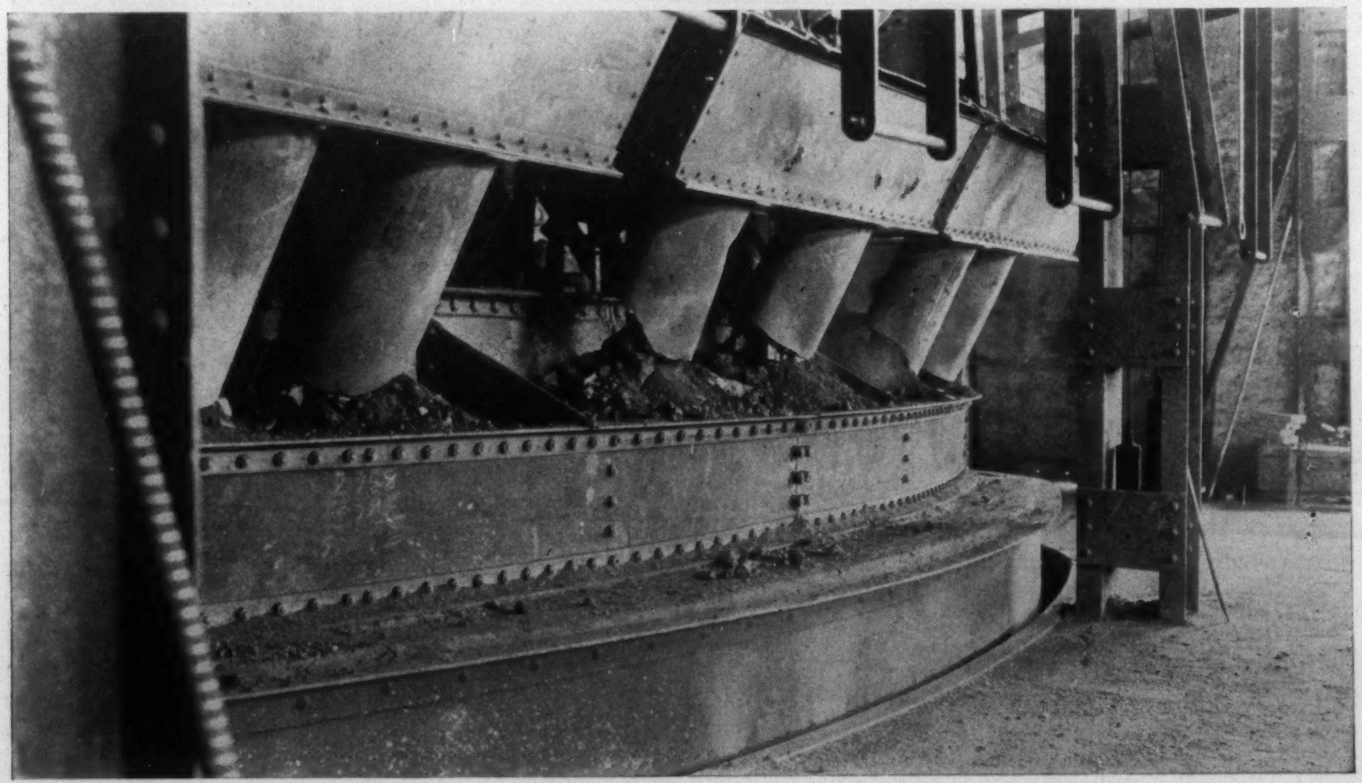
Competition from European Furnaces

Between 1850 and 1860 the great interregnum came in the Norwegian iron production, when the charcoal furnaces, one after the other, had to be shut down because of competition with the large blast furnaces in Central Europe and England. The enormous technical progress following the Franco-Prussian War very materially reduced the costs of production. Iron became so cheap that its field of employment by one stroke was increased tenfold, and in the course of 60 years a hundredfold.

For Norway the sad result of this was that her small charcoal furnaces could no longer compete and she did not have the money to reconstruct the industry to meet the demands of the time. Contributing causes were also the fact that the then known Norwegian mines were smaller and less rich than the Swedish mines and the increasing difficulty in obtaining charcoal within easy reach.

Norway's Raw Materials

However, shortly after the beginning of the new century, there again began to appear possibilities for an iron industry in Norway, no longer based on charcoal, but on electricity produced by water power in which the country abounds. At the same time it had appeared from geological surveys in the western and northern part of Norway that the country had a number of immense deposits of low grade iron ore near the coast. The Sydvaranger and Dunderland fields are the most important, each of 100,000,000 tons of ore. The entire resources of iron ore of Norway are estimated at about 350,000,000 tons of crude ore with



One Section of a Spigerverk Furnace Showing Charging Arrangements.

30 to 36 per cent iron on the surface and at great depths many times this quantity.

Moreover, rapid progress was taking place in the preparation of the ore, particularly by the electromagnetic separation of the finely crushed magnetic iron ore. At Sydvaranger as well as at other mines, the operation is based on this method.

Besides these iron ore deposits, Norway has also great quantities of another important raw material containing 40 to 50 per cent iron, namely pyrites. Not less than 10 per cent of the world's supply of this valuable mineral is found in Norway. After removing the sulphur content by burning at the sulphuric acid and cellulose plants and leaching out the copper and other metals, a so-called "purple ore" is left—a good 60 per cent iron ore which undoubtedly sooner or later will be important, particularly for iron works in the southern part of Norway.

Finally, Norway has also enormous deposits of limestone, and she has charcoal, peat and coal—the coal from Spitzbergen—which, in the event that supplies from the outside should be blocked, will make the country self-sustaining also with regard to reducing materials. Norway is therefore now amply supplied with all raw materials required for its own iron and steel production.

Experiments in Electric Smelting

On this basis, electric smelting has gradually overcome great obstacles. And the difficulties were not made less because charcoal had to be replaced by coke as a means of reduction. Charcoal has become more and more expensive along with the rapid development of the woodpulp industry, while coal and coke with the lower freights have become cheap and easily available raw materials in all countries.

In 1910 the first attempts were made at Tinfos with electric iron smelting with coke. The experiments were successful, and shortly after a similar furnace was erected at Ulefos. At about the same time, a Swedish furnace type, the so-called "Electrometal" furnace, was introduced in a new iron works in Hardanger. But this furnace had been designed for smelting with charcoal and proved unsuitable for coke. The Hardanger works were discontinued in 1913.

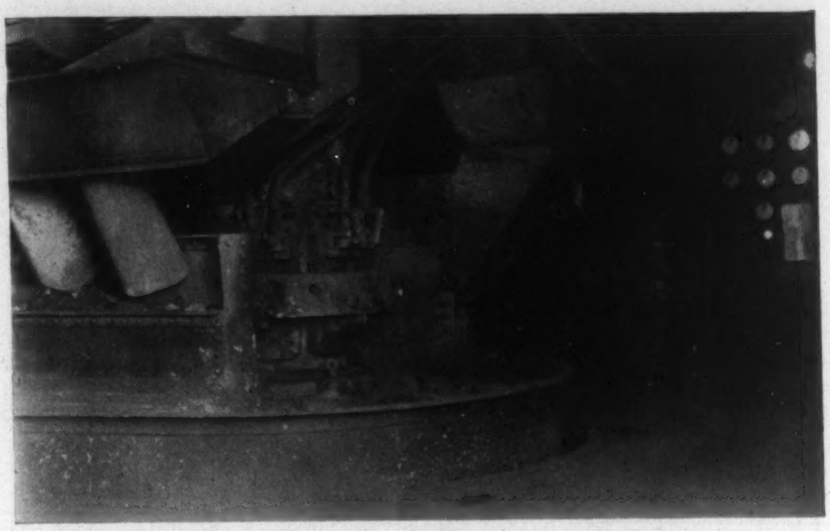
This caused the electric smelting of iron to fall into discredit. However, the difficulty of procuring iron for the country during the World War caused the government to step in and take the initiative in new experiments at Fiskaa Works based on plans worked out by the engineer, Georg Tysland. These experiments produced good results, and, also with the aid of the government, Christiania Spigerverk (nail works) then erected along these lines a furnace of 6000 k.v.a., which was started in 1925.

Changes and improvements have constantly been made later. First by the engineer Tysland and later by the engineer Hole of Christiania Spigerverk. They have succeeded in getting an evenly and quietly working three-phase furnace for the smelting of iron ore with coke. The furnace is closed; it is equipped with a continuous Söderberg electrode, and the gas is sucked off and used in the furnaces of the rolling mills while the slag is used in asphalt for road paving and other things. The next big step was taken when a furnace of 9000 k.v.a. was built in Bremanger in 1927.

Electric Pig Iron as a By-Product

Finally may be mentioned Prof. Harald Pedersen's process of cleansing by means of smelting the bauxite for the manufacture of aluminum and producing as a by-product electric pig iron. Another interesting process may be mentioned, the method of "Norsk Steel" for gas reduction of iron ore without smelting, or low temperature reduction.

Norway is now producing electric pig iron at three places in the country, at the Christiania Spigerverk with the first big Tysland-Hole furnace with an annual production of 12,000 to 13,000 tons; secondly, at the Bremanger Iron Works with a furnace of the same type with a capacity of 18,000 to 20,000 tons a year, and lastly, at the aluminum factory at Höyanger, where by Prof. Pedersen's slag reduction furnace there is produced 4,000 tons of electric pig iron as by-product.



Another View of the Charging Facilities of an Electric Pig Iron Furnace in Norway.

The Pedersen slag analyzes generally about as follows:

	Per Cent
Al_2O_3	47 to 52
CaO	30 to 40
TiO	1 to 3
SiO_2	5+

The by-product pig iron has approximately the following composition:

	Per Cent
Carbon	4 to 4.5
Silicon	0.4 to 0.8
Titanium	0.4 to 0.6
Manganese	0.20
Vanadium	0.20 to 0.25
Chromium	0.20
Phosphorus	0.18 to 0.25
Sulphur	None

The pig iron which is made in Norway today is first and foremost a quality pig iron, namely, vanadium pig iron, hematite and low carbon pig iron for quality castings, of which an important part is for export.

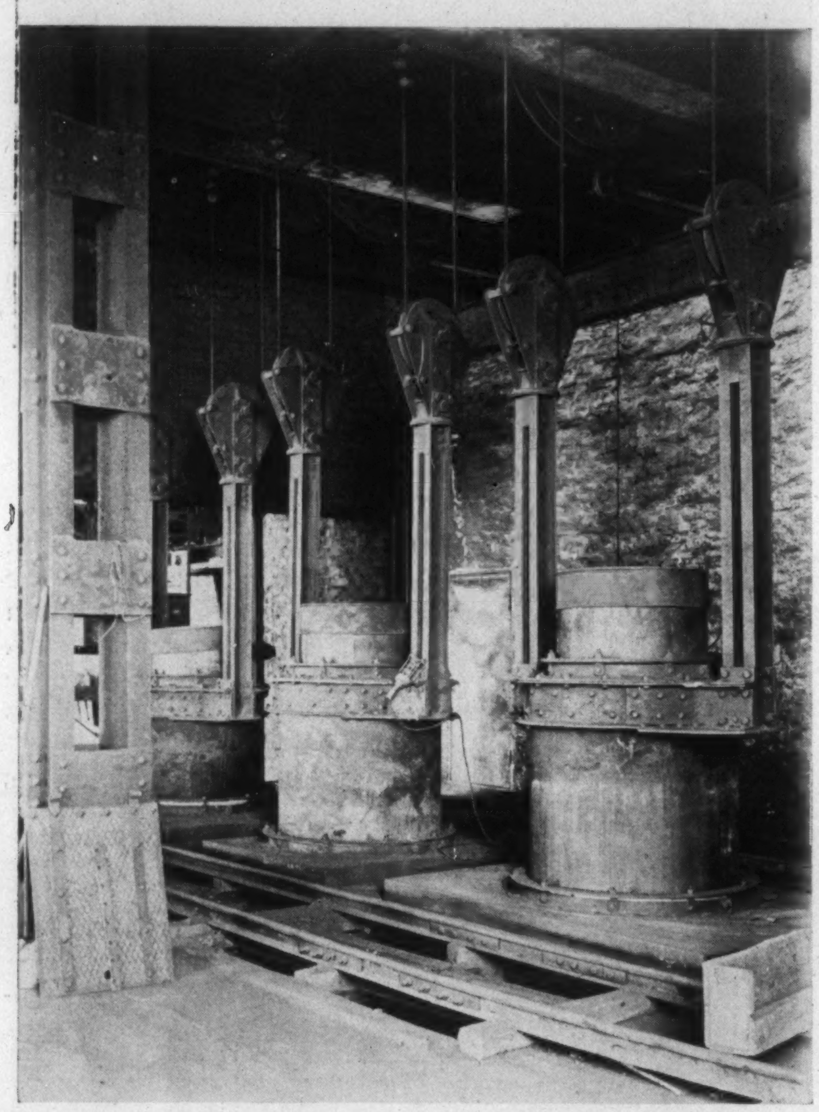
"Norway Iron" has again made a place for itself, both in its own country and abroad. The quality is the same high one that created the name 200 years ago, and the modern preparation of the ore, together with electric smelting, will again raise the production and give the country means to utilize its large iron ore deposits.

Steel Output of Norway

In steel production also Norway has made excellent progress. There is first and foremost the Stavanger Electro-Staalverk, which has made steady progress in quality steel, particularly alloy steel for the tool industry, and in recent years it has also been making rustless iron and steel. This steelworks has manufactured more than 1000 tons of rustless steel annually for home consumption and for export.

Moreover, there may be mentioned the Christiania Spigerverk, which manufactures about 50,000 tons of electric steel annually, which in its own rolling mills is made into rails, skelp, bars, and steel for export. The production has mainly been sold in the domestic market but because of the high quality which Norway's pure ores and the electric furnaces assure, the Spigerverk has in recent years exported a good deal of high grade steel.

In the electric reduction of iron ores the nature of the reducing agent is of the greatest importance. With charcoal the process goes smoothly, even in closed furnaces. The use of coke has been found to present difficulties. The experiments which were made in 1906-1908 in California and other places were probably the first ones in the field of electric iron smelting. To start with, the furnaces were open; later on they were closed (for the purpose of utilizing the gases). A number of furnace types were designed, some of which were never built. Of the furnaces built may be mentioned: The Heroult and Noble furnaces, the Helfenstein furnace, the Electrometal furnace and the Tinfos furnace. Most of them used charcoal, partly with some addition of coke. Of these types only the two last mentioned exist today.



Some of the Electrode Control Mechanism of a Spigerverk Electric Pig Iron Furnace in Norway.

The Electrometal and Tinfos Furnaces

The Electrometal furnace, which dates from 1908, is a charcoal furnace which can stand some addition of coke, at the expense, to be sure, of an increased consumption of power and electrodes and costs of repair. The gases are extracted from and utilized outside of the furnace. The furnace is expensive to buy and to keep in repair and requires, as mentioned, charcoal as the principal reducing agent. It can manufacture only iron of low silicon content, generally below 1 per cent Si.

The Tinfos furnace dates from about 1910 and uses coke exclusively as a reducing agent. The furnace units cannot be made large and the furnace gases have not been utilized. The furnace manufactures gray iron of high silicon content.

In cooperation with the Norwegian Government and "Det Norske Aktieselskap for Elektrokemisk Industri" the so-called Tysland furnace was started in 1925 at Christiania Spigerverk. This furnace was based on experiences from the government's experiments in iron smelting at Fiskaa. Some experience was gained with this furnace, which used coke and coke-dust exclusively as a reducing agent. Besides the use of coke instead of charcoal, the chief consideration for economic operation was that the gases could be extracted from the furnace and be utilized outside. However, this was not a success during the three years in which the furnace was running, nor could it work under particularly high crater tensions. This type of furnace was therefore abandoned and it was superseded by the so-called "Spigerverk" furnace which has now been running for three years.

The Spigerverk Furnace

Up to the present time the principal difficulty, in the electric iron smelting with coke and the like as reducing agents, has been to attain a suitable adjustment of the electrode in the charge, so that the sinking becomes even, and an effective utilization of the heat (cold gases) is obtained. This has been achieved in the "Spigerverk" furnace, which has the following advantages:

1. The electrodes are kept deep down in the charge at the same time that the furnace is working at high crater tensions. Thus, the furnace units can be large and the gases assume low temperatures as they give off their heat to the mix before leaving the furnace.
2. By exclusive use of coke and coke-dust as a reducing agent, a sulphur purification is attained which gives iron of charcoal quality.
3. The utilization of the furnace gas is practically complete. The gases contain 80 to 90 per cent of combustible components. About 650 cubic meters of gases per ton of pig iron with a value of about 2600 cal. per cu. m. are obtained.
4. The furnace can smelt mixes with an exceedingly high content of fine-grained components without causing any irregularities in the working of the furnace.
5. The furnace produces iron of the most different qualities, from pure white iron of very low silicon content to iron with 4 per cent silicon or more. At the same time the other components (manganese, etc.) may be varied as desired. There is not much difference in the analyses from one tapping to another and thus it is easy to keep the desired components within comparatively narrow limits.
6. The furnace construction is simple and the furnace therefore cheap to buy. The costs of repair are very low. The arc is not exposed to heat strains as is the case with other closed furnaces. Interruption in the operations very rarely occurs.

The power consumption of the furnace varies from 2300 to 3000 kw. hr. per ton of pig iron, mainly depending on the silicon content of the pig iron.

The Spigerverk furnace must be considered entirely tried out and it is today the only electric pig iron furnace which, by using cheap reducing agents (no charcoal), utilizes the gases and permits the manufacture of any quality of iron. At the same time the furnace units can be made larger than has hitherto been possible for other furnace types.

SILVER-INDIUM ALLOYS

Notes on the Aging of Silver-Rich Ones

By **TRACY C. JARRETT**

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IT IS THE OBJECT of this paper to present some of the characteristics of the silver rich-silver indium Alloys. In this investigation alloys of one, two and four percent indium were studied. The element indium, one of the more rare metals, is now for the first time being produced upon a commercial scale. This explains in part the lack of available technical data of its alloys, although some of the properties of the metal are known.[1]

The alloys investigated were melted in graphite crucibles in an induction furnace, and the melts were cast in warm steel molds. To prevent the loss of indium, the silver was melted in one graphite crucible, then poured into another which contained the indium, after which the alloy thus formed was remelted and cast. By this procedure the indium, coming in contact with the molten silver would melt and alloy with the silver before its oxidation could occur. From visual observations made during the melting of the silver-indium alloys, the melting point of silver appeared to be lowered by the presence of indium.

By rolling the cast bars and rods, it was possible to reduce them 80 to 90 per cent without annealing. The specimens used in the aging tests were 1 x 1-2 x 1-8 in.; those used for the electrical conductivity were 0.125 in. in diameter. This wire was drawn through diamond dies to insure a uniform diameter of the test specimens.

A Kelvin double bridge was used for making the electrical conductivity tests. This method is sufficiently accurate and sensitive to detect small changes in conductivity.

The composition of the alloys by weight which were given the age-hardening treatment is as follows:

Alloy	*Indium*	*Silver*
I.	1.0	99.0
J.	2.0	98.0
K.	4.0	96.0

As events proved, the time and temperature of aging have little effect upon the change in hardness of any of the three compositions, previously made age-hardenable by quenching from 700 deg. C.

In Figs. 1 to 3, the effect of such aging is shown for four different aging temperatures for the three compositions. One sees here that, after a period of some 200 hrs., there is a maximum change of about 25 points "Rockwell E Scale." In the quenched condition the hardness of alloys I and J was greater than that of alloy K. The change in hardness takes place

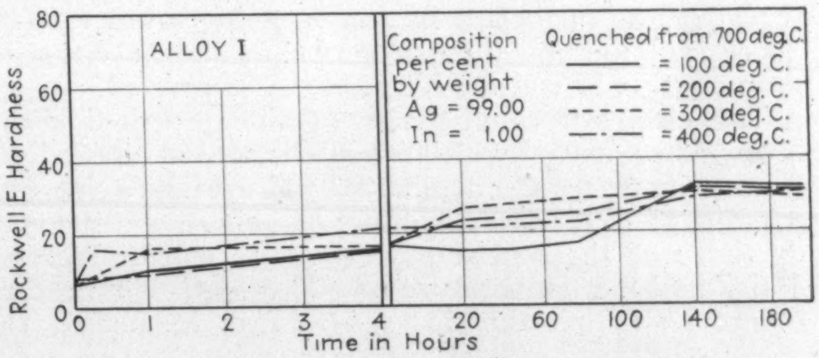


Fig. 1. Increase of Hardness with Time for Alloy I.

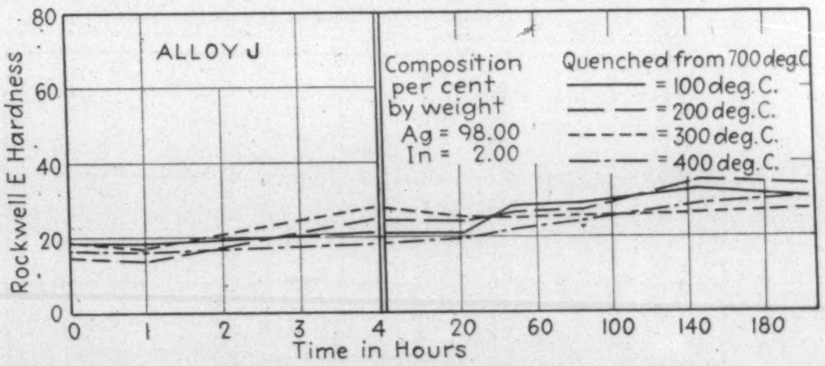
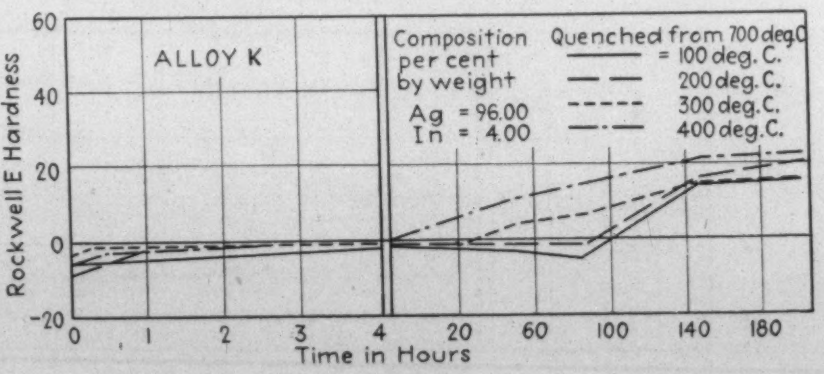


Fig. 2. Increase of Hardness with Time for Alloy J.

Fig. 3. Increase of Hardness with Time for Alloy K.



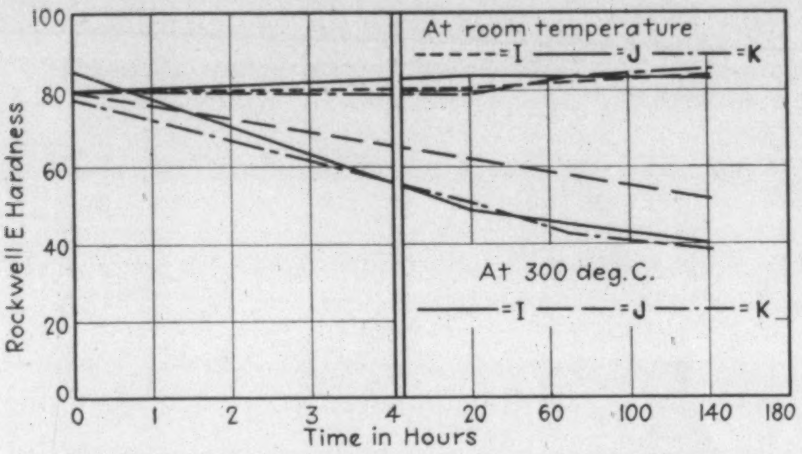


Fig. 4. Changes in Hardness upon Aging after Cold Working.

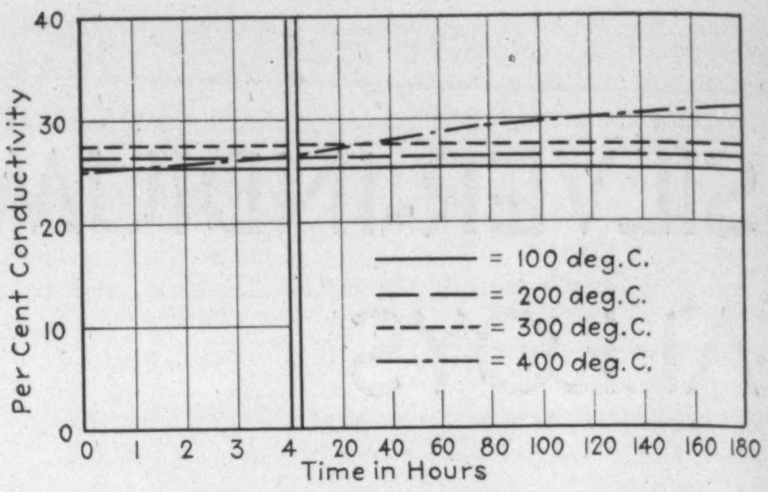


Fig. 7. Effect of Aging upon Conductivity for Alloy K.

more rapidly in alloy I than in alloys J and K. The final (200 hr.) hardness is about the same in all of the alloys after aging, although they had different hardness values after quenching.

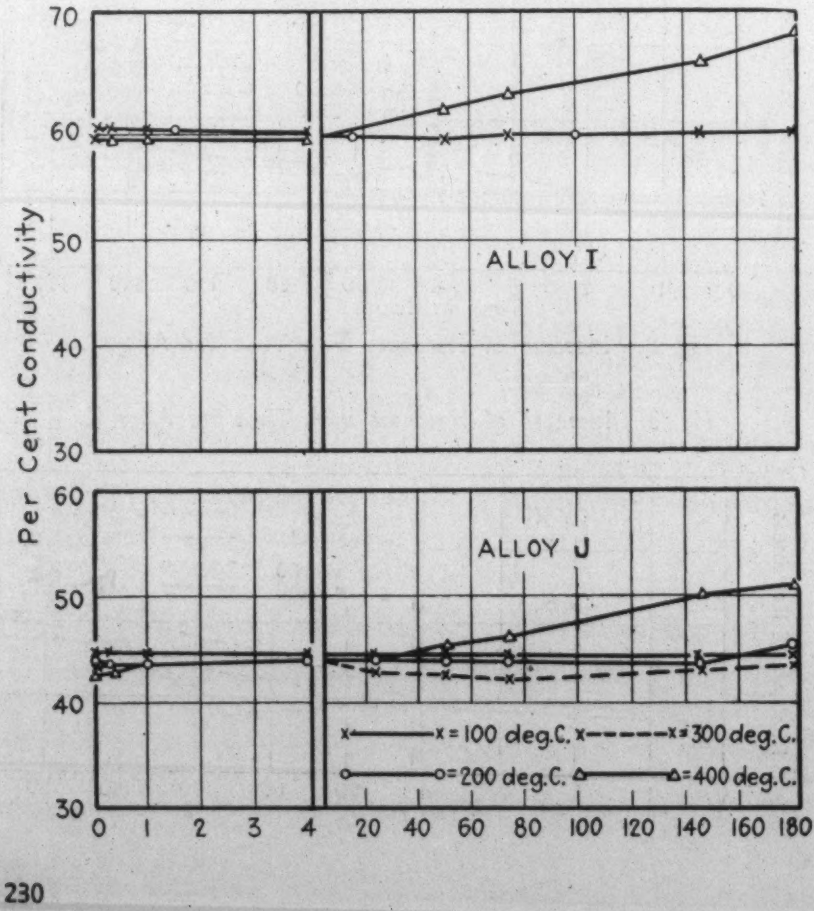
When the alloys were aged at room and at elevated temperatures after cold work, (Fig. 4) very little change occurs in the specimens aged at room temperatures, while those aged at a temperature of 300 deg. C. undergo a decided softening. This softening action at 300 deg. C. is doubtless due to the recrystallatization of the cold worked material. It should be noticed that the hardness after cold work is greater than the maximum hardness obtained by the aging of non-deformed material. The composition has a decided effect upon the hardness change in these alloys. The hardness of the alloys as quenched increases, going from zero to 2 per cent indium, then drops below the hardness of pure silver when 4 per cent indium is present.

The electrical conductivity of the quenched alloys is low as compared with pure silver, and as the indium content increases the conductivity decreases. (See Fig. 8.) Figs. 5 to 8 show the effect of aging upon the conductivity of the quenched alloys. As shown in Figs. 5, 6, 7 and 8 a temperature of 400 deg. C. is necessary before an appreciable increase occurs in any of the alloys. The change in per cent conductivity of alloy K aged at 400 deg. C. is somewhat greater than in the case of alloys I and J aged at this temperature. (See Fig. 8).

Indium, if one is to judge from the photomicrographs of Figs. 9 to 13, appears to have a decided effect on the grain size of the alloy and on the number of twins present. In the quenched alloys I and J at 100 diameters, Figs. 9 and 10, the grain size is very fine; while in the quenched alloy K, Fig. 13, the twinned grains are very large. It is possible the fine grains in alloys I and J are responsible in part at least for the greater quenched hardness of the alloys. There appeared to be little difference in the quenched and the fully aged structures and for that reason the photomicrographs of the aged alloys are not included. In the unetched condition it was impossible to detect the presence of a second phase.

Note: The work described in this paper is part of a thesis presented in fulfillment of the requirements for the degree of Doctor of Science in metallurgy from Harvard University.

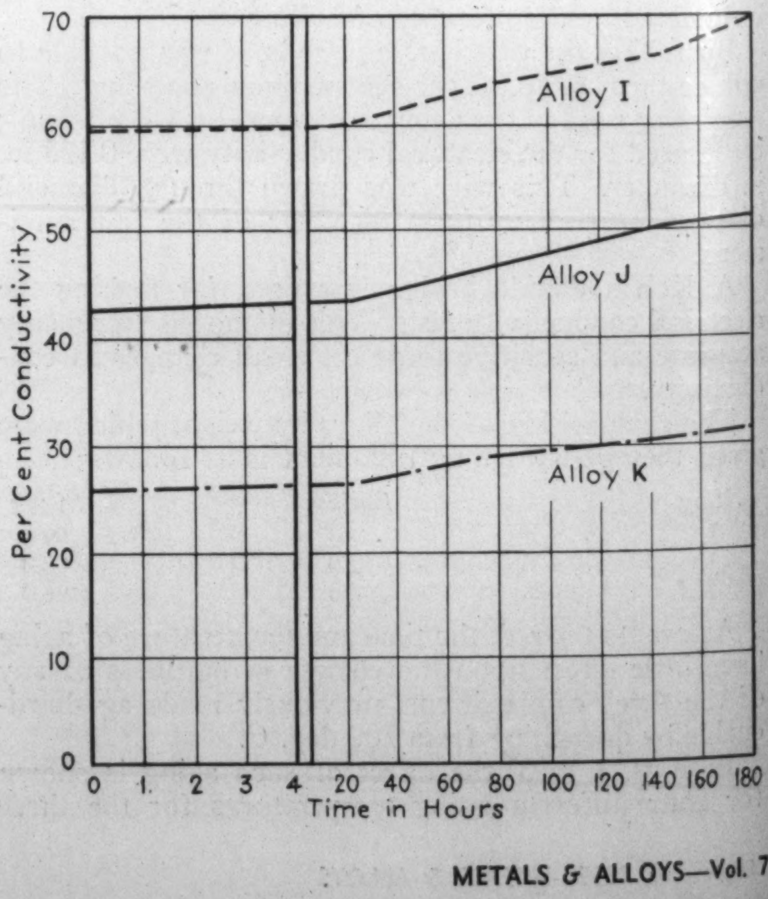
Fig. 5. Effect of Aging upon Conductivity for Alloy I.
Fig. 6. Effect of Aging upon Conductivity for Alloy J.



Reference

[1]W. S. Murray, *Industrial Chemistry,* Vol. 24, June, 1932, page 686.

Fig. 8. Effect of Composition upon Conductivity after Aging at 400 deg. C.



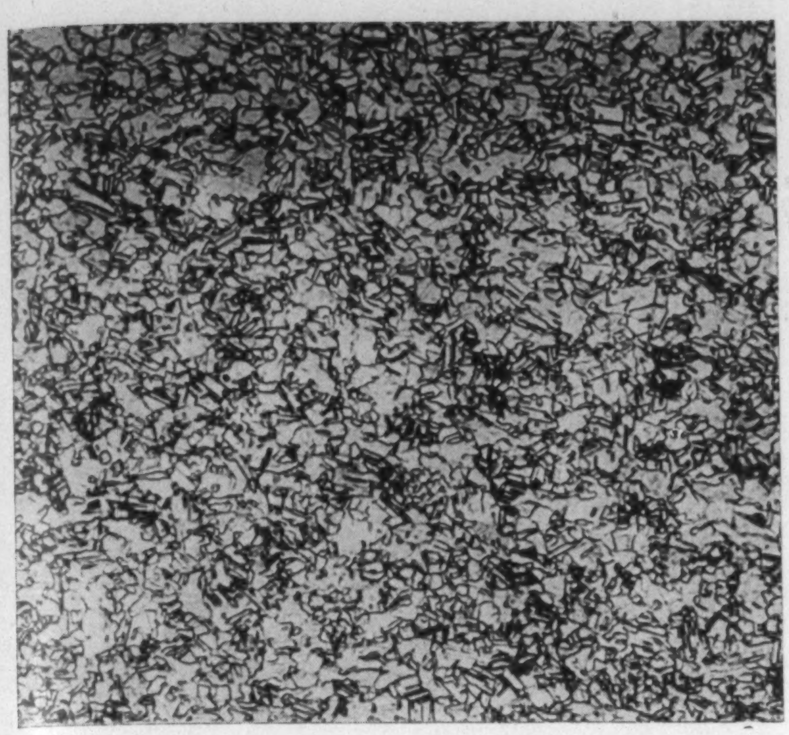


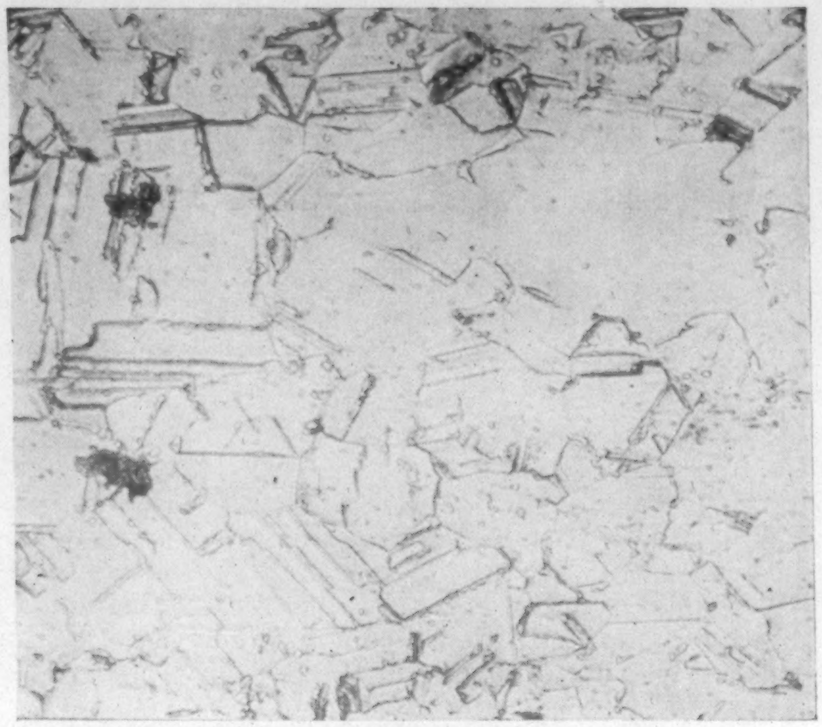
Fig. 9. (Top Left) Structure of Alloy I, Quenched from 700 deg. C. Magnification 100 diameters. Etched with solution of $K_2Cr_2O_7 + H_2SO_4$.

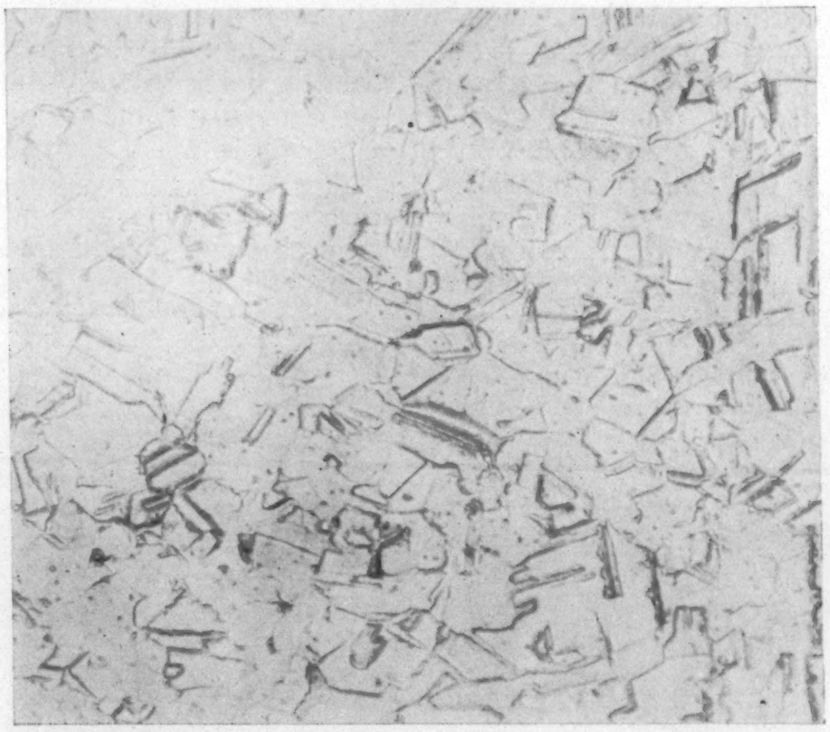
Fig. 10. (Bottom Left) Structure of Alloy J, Quenched from 700 deg. C. Magnification 100 diameters. Etched with solution of $K_2C_2O_7 + H_2SO_4$.

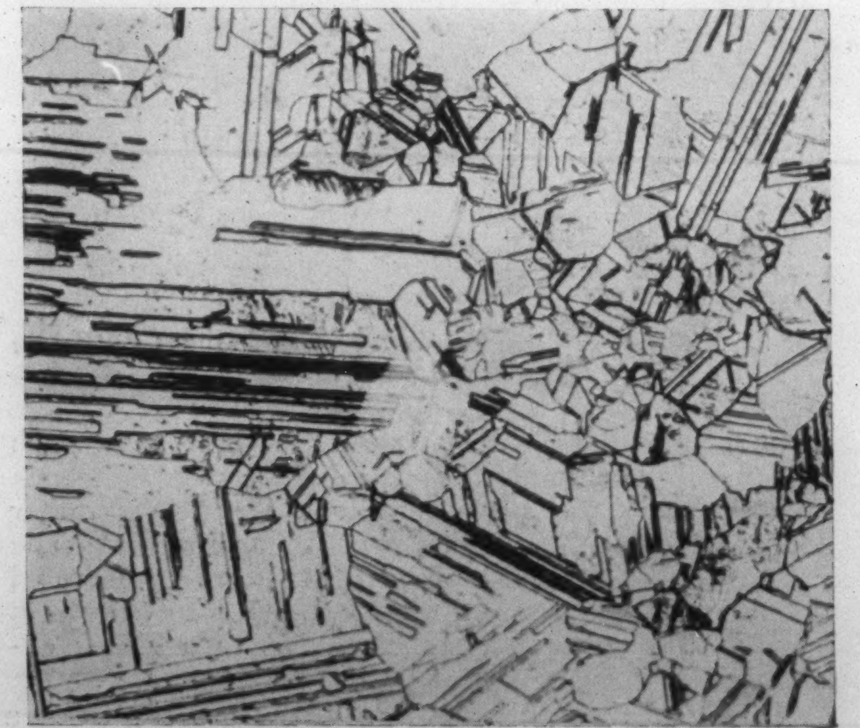
Fig. 11. (Top Right) Structure of Alloy I, Quenched from 700 deg. C. Magnification 500 diameters. Etched with solution of $K_2Cr_2O_7 + H_2SO_4$.

Fig. 12. (Right Center) Structure of Alloy J, Quenched from 700 deg. C. Magnification 500 diameters. Etched with solution of $K_2Cr_2O_7 + H_2SO_4$.

Fig. 13. (Bottom Right) Structure of Alloy K, Quenched from 700 deg. C. Magnification 100 diameters. Etched with solution of $K_2Cr_2O_7 + H_2SO_4$.







Unusual Dendrites in Sheet Steel

By ALFRED BOYLES and M. L. SAMUELS

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DURING THE EXAMINATION of some specimens of commercial box annealed sheets a peculiar type of structure was noticed in samples showing abnormal grain growth. The material in question had the following analysis:

C	Mn	P	S	Si	
0.03	0.36	0.020	0.013	0.010	per cent

It had been subjected to the usual sheet mill procedure in which sheets rolled from breakdowns are given an annealing cycle of some 30 hours or more, the maximum temperature reached being about 1300 deg. F. Material of this type normally contains no pearlite, the carbide present occurring in massive form at the grain boundaries. In the sheets under discussion, some of the grains were abnormally large, and in the central portion of such grains fine needle-like markings appeared after a light etch in 3 per cent alcoholic nitric acid. Fig. 1 shows a typical case. Such an appearance suggested iron nitride but analysis showed only 0.003 per cent nitrogen which is rather low even for a steel of this type. Upon continuing the etching to 20 seconds, some of the grains revealed definite tree-like formations such as those shown in Fig. 2. So unusual a structure led to a closer examination.

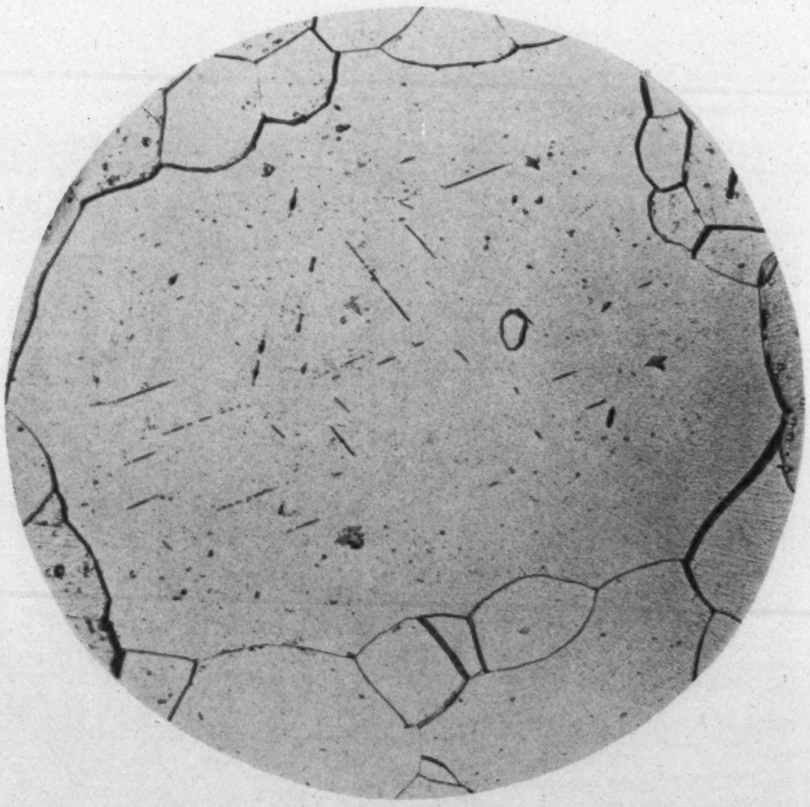


Fig. 1. Needles in a Large Ferrite Grain. Etched with 3 per cent nitric acid. Magnification 100 diameters.

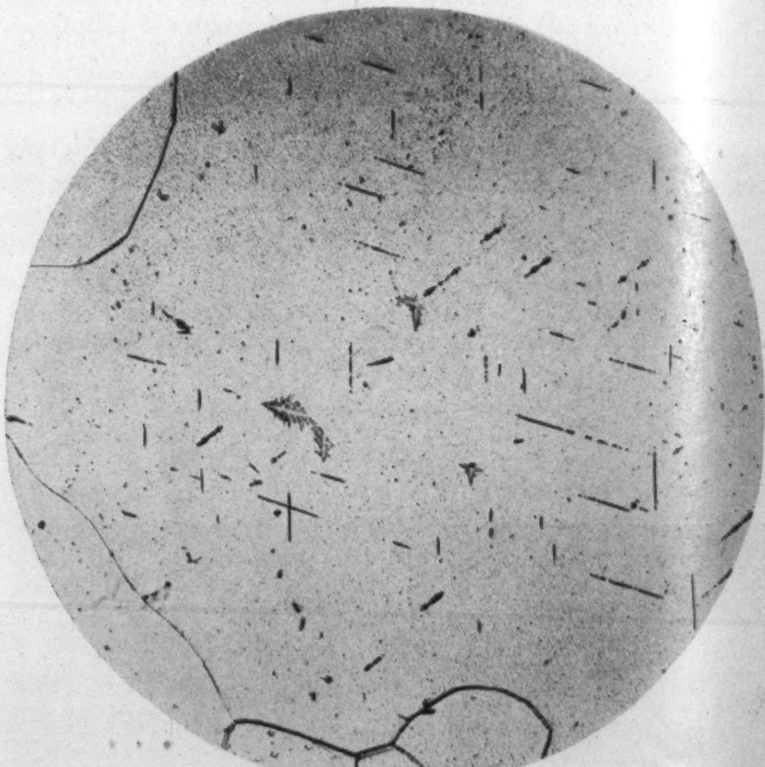


Fig. 2. Needles and Dendrites in a Large Ferrite Grain. Etched with 3 per cent nitric acid. Magnification 100 diameters.

In Fig. 3 the central part of Fig. 2 is shown at a higher magnification. Here four dendrites apparently occur, very definitely oriented with respect to one another and to the needles appearing in the same grain. Fig. 4 shows the same field with an additional 20 seconds etching. Two of the dendrites of Fig. 3 are seen to be arms of one large dendrite which has been uncovered by the etching attack. In Fig. 5, with 20 seconds additional etching, two new dendrites have been partly uncovered, and in Fig. 6 with 20 seconds more etching, these are fully revealed and still other new dendrites have appeared. The original dendrites of Fig. 3 are completely etched away. Etching of this same grain was continued up to three minutes, at which stage the surface was too rough for further study. All the dendrites shown were dissolved by the etching solution, the average life being about one minute.

It was evident from these observations that the dendrites were arranged along planes nearly parallel to the plane of polish and that they were quite thin and flat, since the largest one was hidden by the amount of ferrite removed in 20 seconds etching. The definite geometric arrangement of the dendrites and needles suggested a relationship to the crystallographic planes of the iron. Assuming a random orientation of grains, the dendrites should be cut at all angles by a plane of polish. Some of them would be seen in cross section and, since they were known to be thin, it was natural

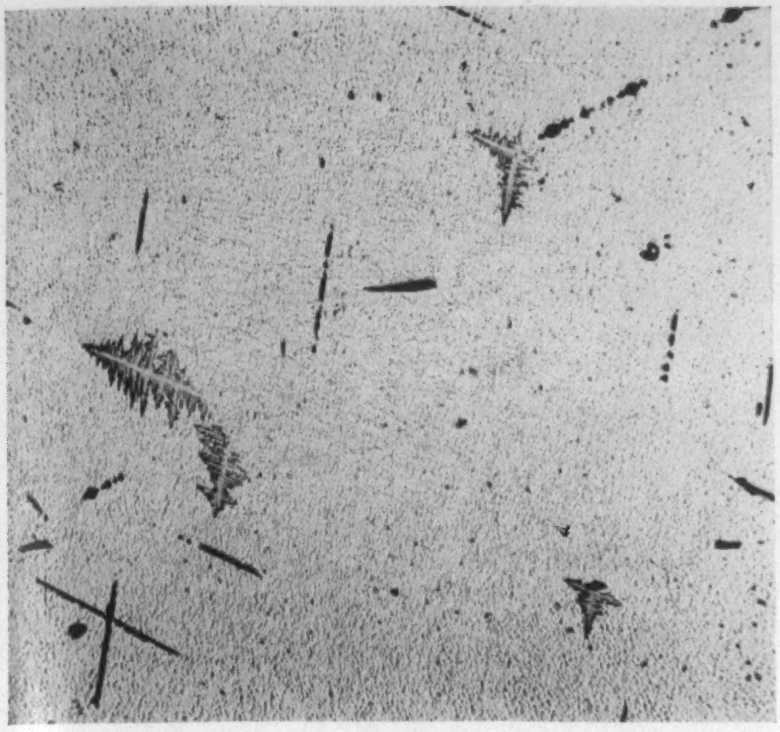


Fig. 3. Details of Fig. 2. Etched 20 seconds. Magnification 250 diameters.

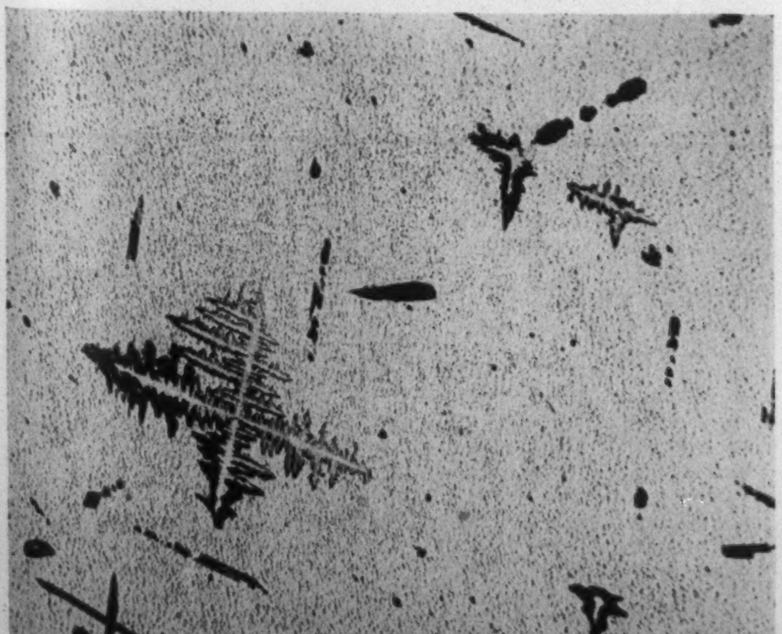
to suspect that the needles and dendrites were identical.

A large number of coarse grained sheet specimens were examined by polishing the flat side of the sheet so as to get a larger polished area as well as the cross section of the sheet. It was found that relatively few grains showed dendrites as nearly in the plane of polish as those in Fig. 2. Numerous grains were found in which the dendrites were cut at an angle such as that shown in Figure 7. Here the right hand side of the dendrite has been ground away in polishing while the left hand side is concealed under ferrite, as may be seen by comparing it to the tiny dendrite just to the left. Most of the grains showed nothing but needles. It was further noted that in every grain showing dendrites nearly in the plant of polish, a definite angular relationship existed among the needles.

In an effort to establish the identity of dendrites and needles, some samples were prepared with two polished faces at right angles, one being the cross section of the sheet. Since it was a matter of chance, the work was continued until a grain was found having dendrites nearly in the plane of polish on one face, and the section of the same grain at right angles was then studied. Fig. 8 is a drawing made from photographs of two such faces in a single grain. Section A shows dendrites nearly in the plane of polish and needles lying in three directions as indicated. The dotted line XY marks the new section at 90 deg. to the plane of the paper. This new section B contains needles lying in six directions but no dendrites are present. Continued etching failed to uncover any.

The occurrence of six directions on a plane of polish suggested an arrangement along the planes of a dodecahedron, with the Miller Indices 110. A rhombic dodecahedron has been drawn beside Section A with one of its faces, A′ in the plane of the paper. Dendrites lying along the faces 1, 2 and 3 would appear as needles on Section A. Those on the remaining faces of the dodecahedron would appear as needles parallel to 1, 2 and 3. The dotted line X′Y′ indicates

Fig. 4. Same as Fig. 3. Etched 40 seconds. Magnification 250 diameters.



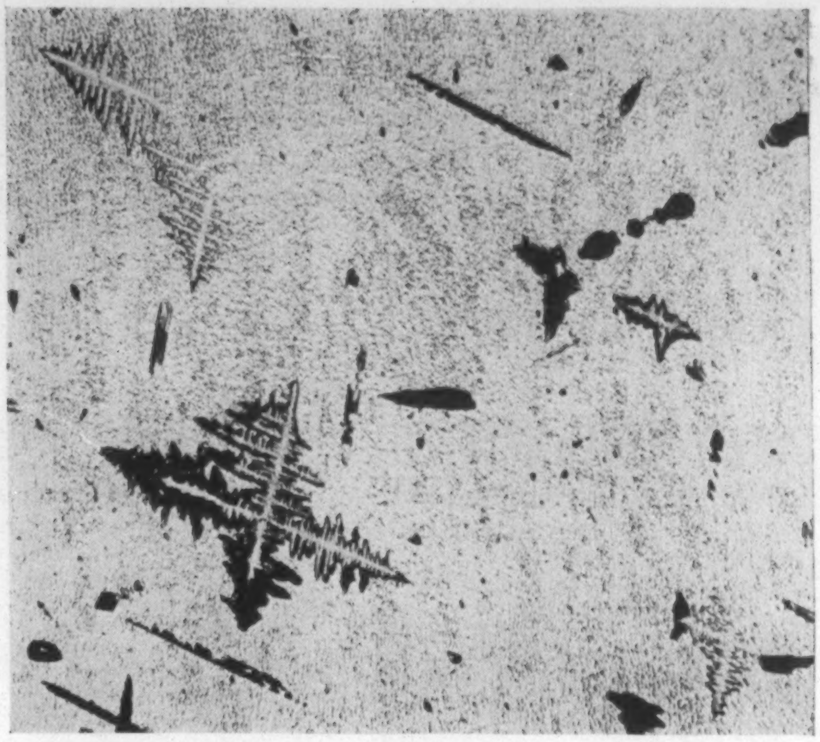
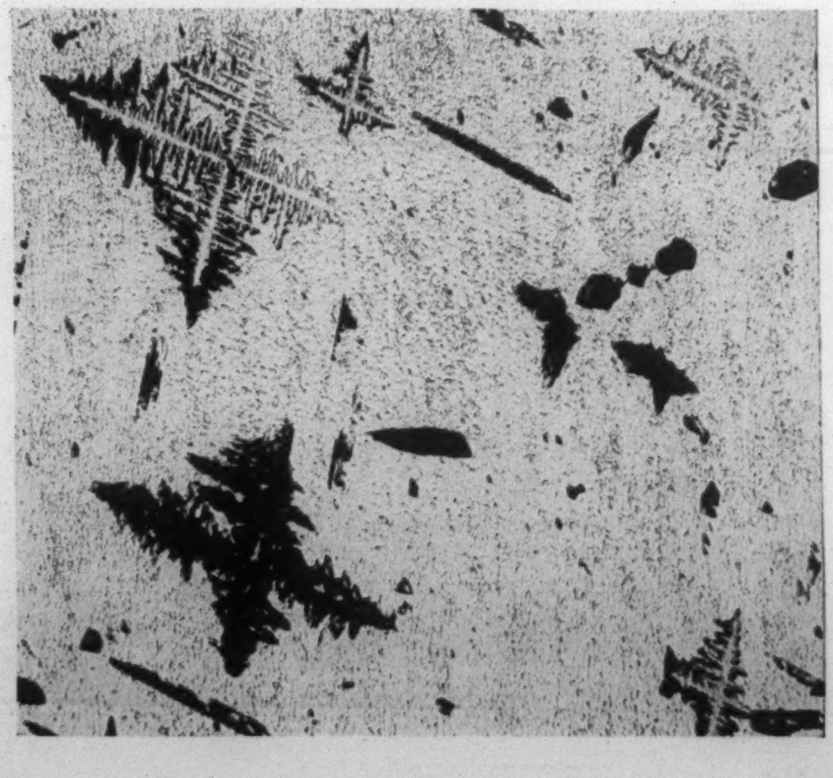


Fig. 5. Same as Fig. 4. Etched 60 seconds. Magnification 250 diameters.

Fig. 6. Same as Fig. 5. Etched 80 seconds. Magnification 250 diameters.



the plane of Section B at 90 deg. In the lower view the crystal has been turned to bring the plane X′Y′ into the plane of the paper. Intersections of plane X′Y′ with the crystal faces are shown as dotted lines and these have been numbered to correspond to the six directions shown by the needles in Section B. The original face A′ is now on top. A dodecahedral arrangement seems to satisfy the conditions in this particular grain.

It remained to show definitely that a needle appearing in one polished face would become a dendrite when viewed from another angle. For this purpose the grain shown in Fig. 9 was selected. Referring to Section A in Fig. 8, it will be seen that face 3 of the dodecahedron is perpendicular to face A′, while faces 1 and 2 form angles of 120 deg. with it. The acute angle of the face A′ is about 70 deg. and 30 min. In Fig. 9 two sets of needles form an angle of about 73 deg. as indicated. It was therefore assumed that the third set of needles was perpendicular to the plane of polish, and it was proposed to section the grain at an angle of 90 deg. parallel to and through the needle marked A. The actual section obtained is indicated by the dotted line in Fig. 9 which runs through the needle but is not quite parallel to it.

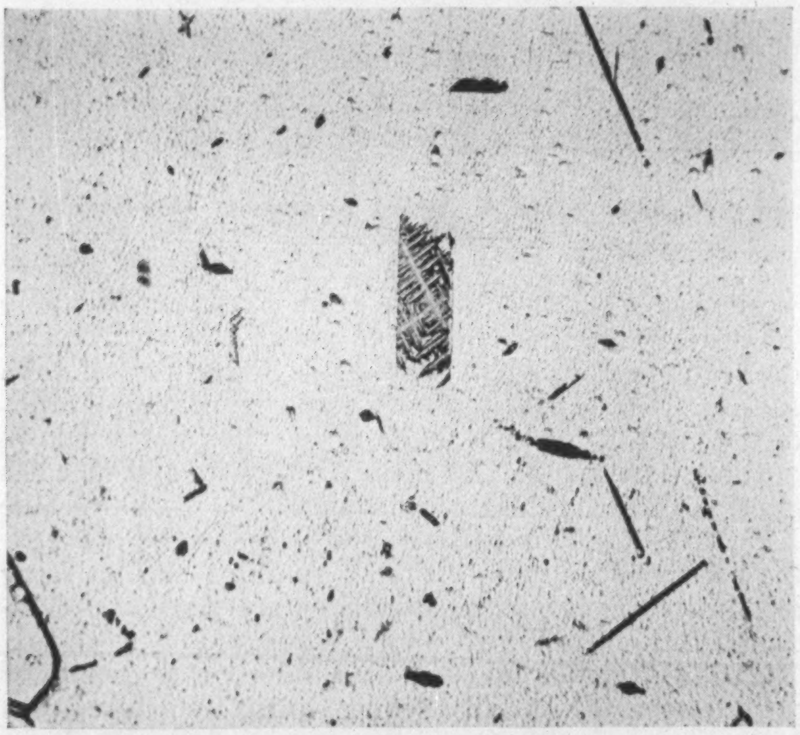


Fig. 7. Dendrite Cut at an Angle. Etched with 3 per cent nitric acid. Magnification 250 diameters.

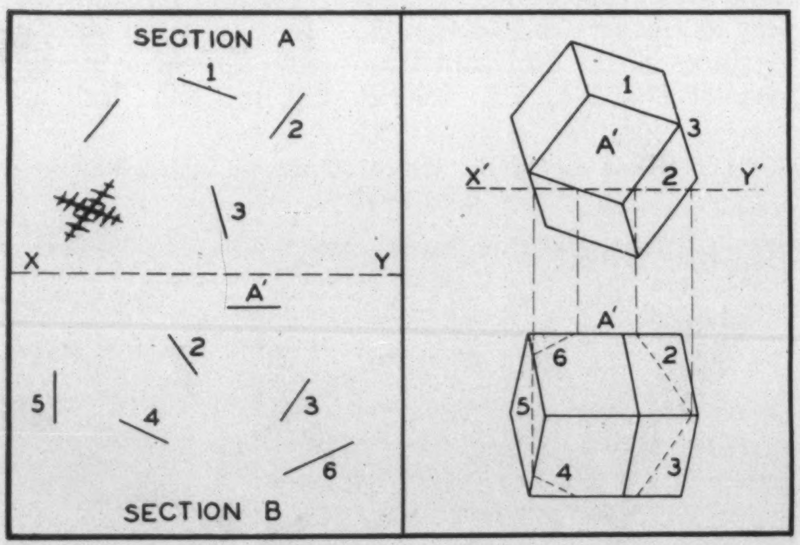


Fig. 8.

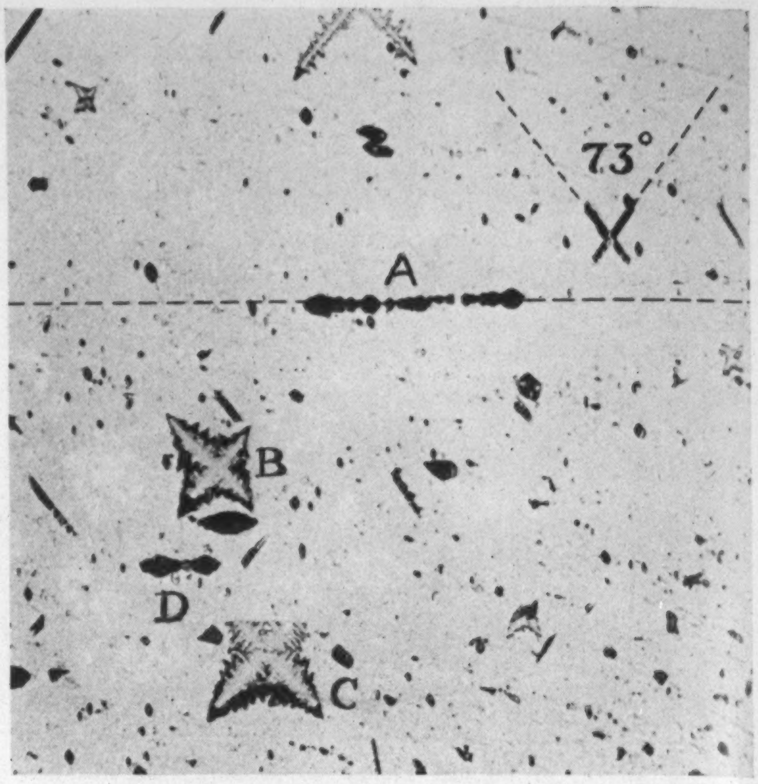
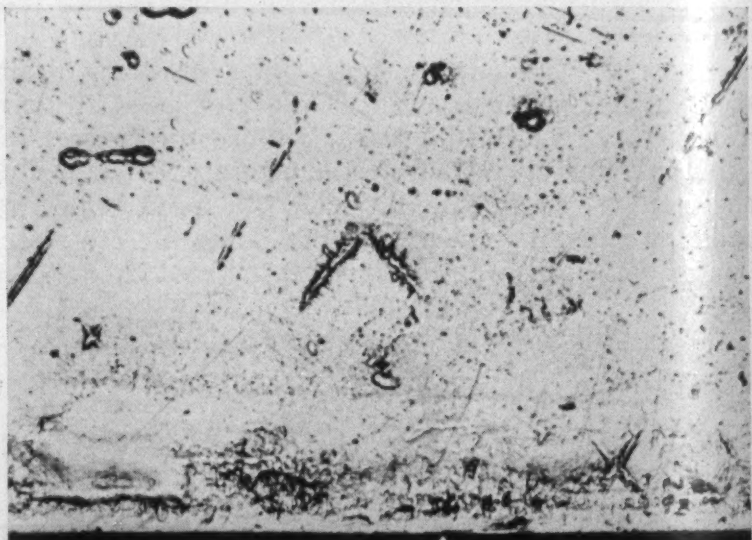


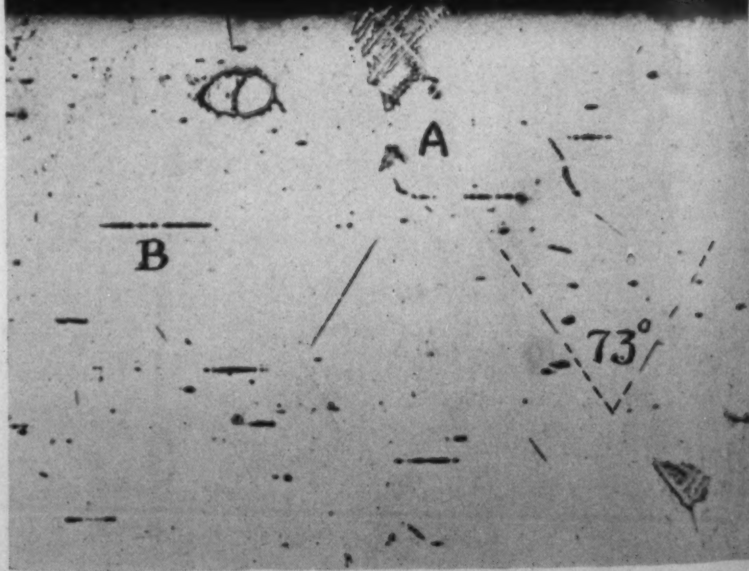
Fig. 9. Grain Selected for Sectioning. Etched with 3 per cent nitric acid. Magnification 250 diameters.

Fig. 10 shows the same face as Fig. 9 after the new section had been cut and polished. The original surface has been marred somewhat in the process of mounting and polishing but enough features remain to establish the precise location of the new face. Fig. 11 is a view of the new 90-deg. section in which the

Fig. 10. (Upper) Same Grain Shown in Fig. 9 after Cutting and Polishing a New Section at 90 Deg. Magnification 250 diameters.

Fig. 11. (Lower) View of New 90 Deg. Section Showing a Dendrite at A. Magnification 250 diameters.





needle A appears as a typical dendrite. Part of the dendrite is still covered by ferrite, due to its slight inclination. The double arrow indicates the same point on both faces, as determined by micrometric measurements from the grain boundary. It is interesting to note that both faces of the grain show the same arrangement of needles. Needle B in Fig. 11 belongs to that family which appears as dendrites in the original section.

From these observations it seems reasonably certain that the needles and the dendrites are one and the same thing. Examination at higher magnifications confirms this and shows why the needles appear so thick at low powers. In Fig. 12 the lower portion of Fig. 9 is shown under oblique illumination, the direction of the light being from the top of the page. The objective is focused on the background and it is evident that both dendrites and needles are standing in relief. Under vertical illumination the ridge D appears dead black as seen in Fig. 9. By raising the focal plane three microns, the top of the ridge comes into focus and along its center a thin black line is visible. This is the dendrite proper, perpendicular to the plane of polish.

That such is the case may be seen by reference to Fig. 9 where D is shown to be parallel to A. The dendrites E and F, Fig. 10, are inclined 120 deg. to the plane of polish, and they also project above the general surface as shown at E in Fig. 13 and F in Fig. 14. The delicate lace-like structure of the dendrites is evident in these photographs. They also show why a certain depth of etching is required to reveal them in their entirety when they lie nearly in the plane of polish. It is necessary to remove a layer of ferrite the thickness of which depends on the inclination of the dendrite to the polished face. The dendrite is then left on top of a little plateau of iron. The probability of a dendrite being oriented to a given plane within the limits of its own thickness is small. For this reason dendrites have never been observed in unetched specimens.

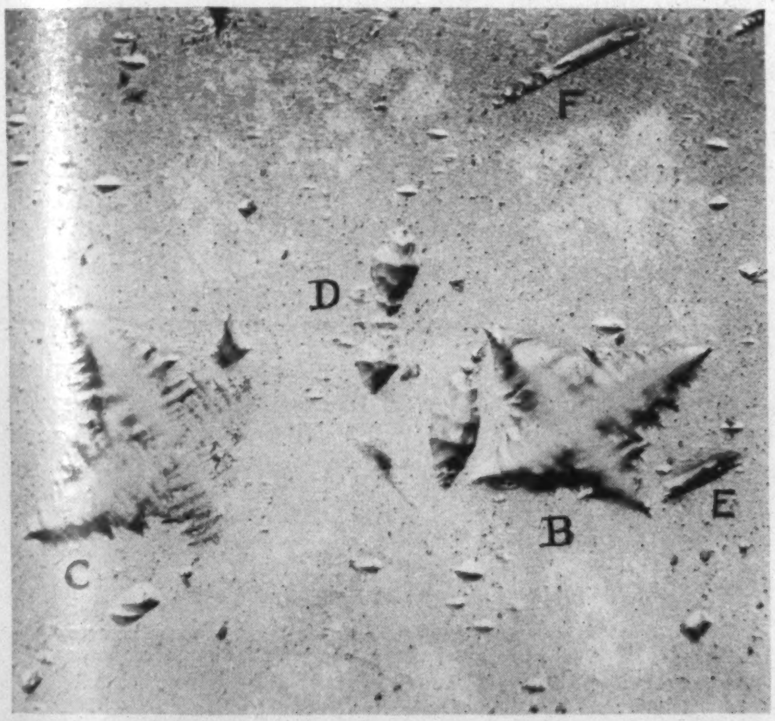


Fig. 12. Focused on Background. Etched with nitric acid. Magnification 500 diameters.

Method of Producing the Dendrites

The structures described so far were observed in commercial sheets which had been box annealed after hot rolling. Apparently the dendrites are produced under conditions favoring excessive grain growth for they are not found in grains of normal size. The smallest grain in which they have been seen is about 0.02 in. in diameter. In mixed structures the larger grains may show them in abundance while the small grains in the same piece have none whatever. It was also noticed that the dendrites have a decided preference for the central part of the grains, as shown in Figs. 1 and 2. Besides conditions favoring germination, a very slow cooling rate from the annealing temperature is necessary. No extended tests have been made on these conditions but a very simple method has been found for producing the dendrites for experimental study. Samples of sheet or sheet bar are heated to about 1850 deg. F. and cooled in air. They are then given a slow box anneal at about 1300 deg. F. after which treatment large grains and dendrites are found. In sheet bar samples only the surface portion granulates but the dendrites produced are identical to those in the sheets. In this manner dendrites have been developed in steel from four different sources, widely distributed geographically.

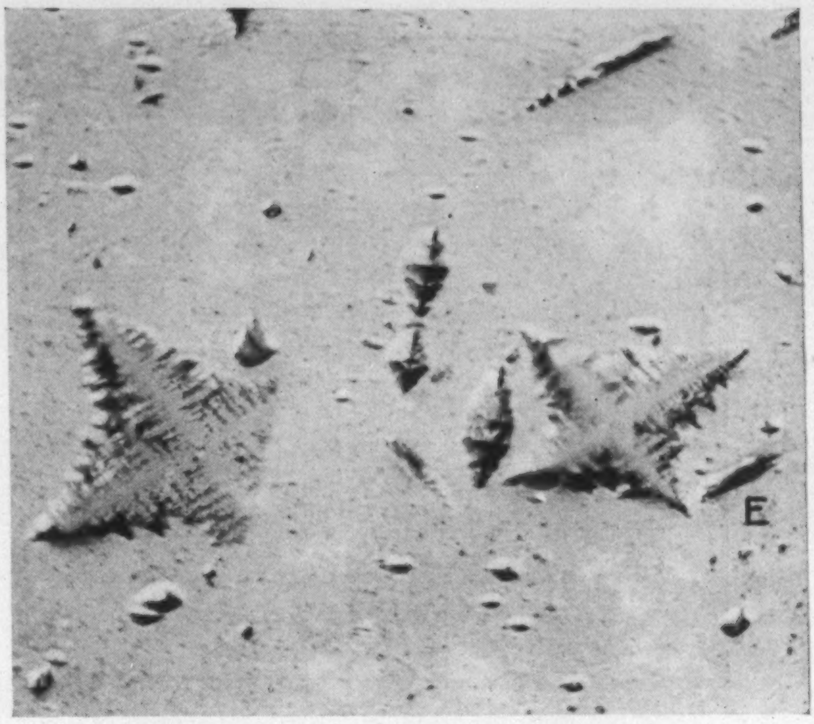
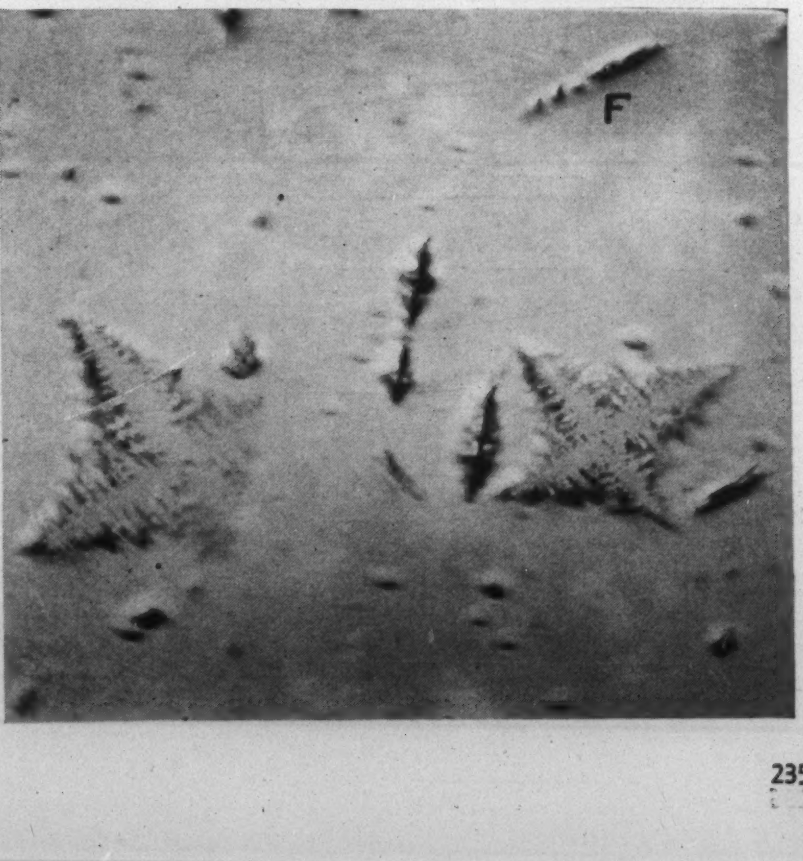


Fig. 13. Focal Plane Raised 3 Microns. Magnification 500 diameters.

Fig. 14. Focal Plane Raised 5 Microns. Magnification 500 diameters.



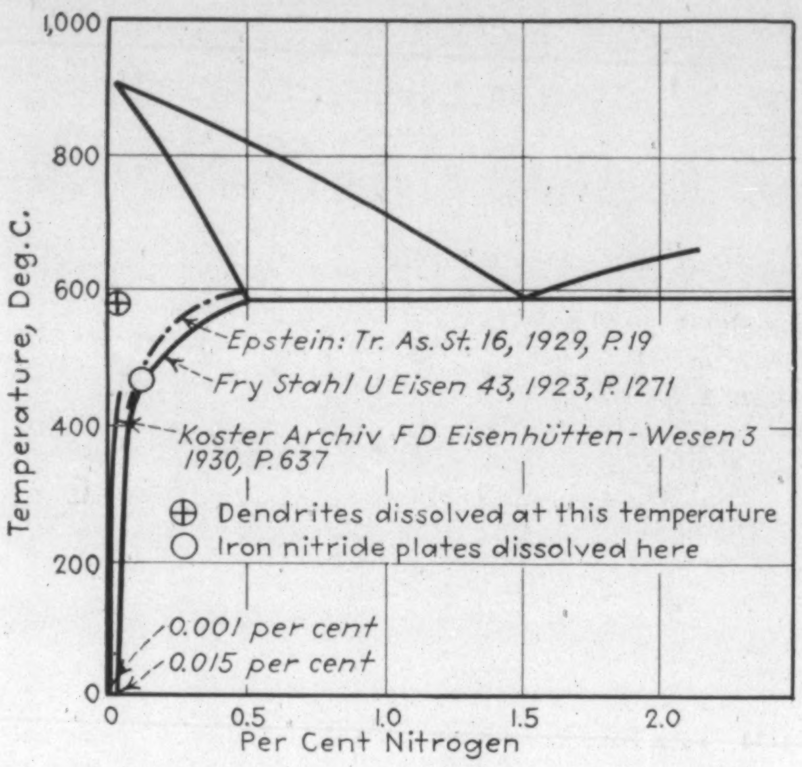


Fig. 15. Temperatures at which Dendrites and Iron Nitride Plates Dissolve.

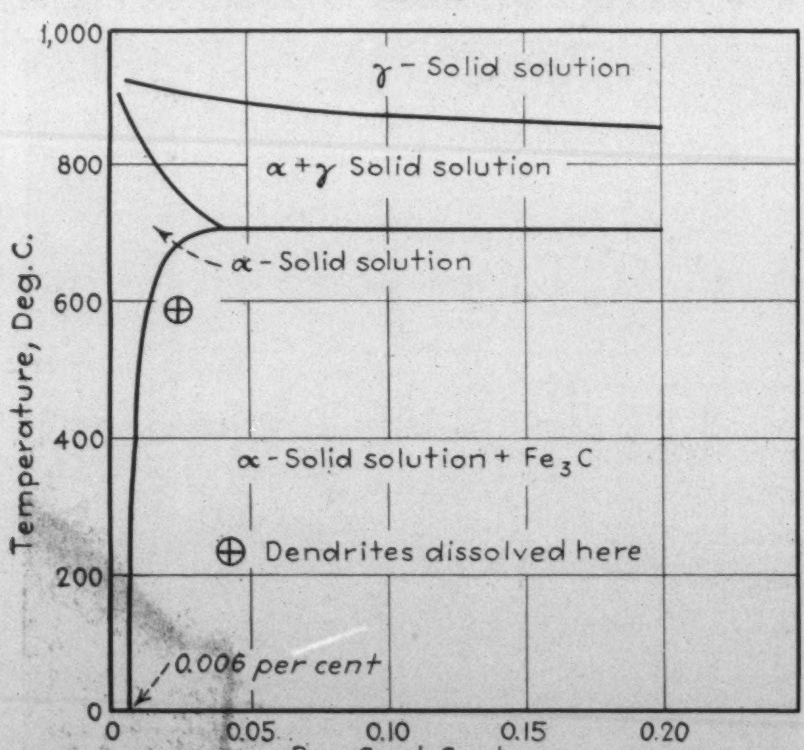
The dendrites have been found abundantly in deoxidized, semi-deoxidized and black sheets. This seems to indicate that the annealing atmosphere is not responsible for the formation. In one case we produced typical dendrites in the laboratory in commercial sheets by a treatment simulating box annealing very closely. Some 22 ga. sheets were being purified in hydrogen for another purpose. The sheets were held at 1900 deg. F. for 72 hrs. in a hydrogen atmosphere and cooled to room temperature in 22 hrs. Upon examination these sheets showed abnormally large grains and typical dendrites. An analysis was made showing the following results:

C	P	Mn	S	O	N	
0.02	0.020	0.13	0.040	0.0089	0.0088	per cent

Efforts to Identify the Dendrite Material

It was natural to presume that the material was iron nitride, although dendrites of iron nitride in steel have not been described, and an analysis showed only 0.003 per cent nitrogen. First efforts at identification were along synthetic lines, that is, it was proposed to make up melts from electrolytic iron which would differ in content of nitrogen, oxygen and carbon and then to give these melts the treatment known to produce dendrites. In this way the most likely substance was to be chosen. However, it was not found feasible in practice to produce melts sufficiently low in the elements not wanted. For example, the "nitrogen free" melt contained 0.003 per cent nitrogen, which is equal to the nitrogen content of the commercial sheets. Because of such difficulties, efforts at synthesis were abandoned and attention was directed to other means of identification.

Fig. 16. (After Koester). Indicating Where Dendrites Dissolved.



(a) **Solution on Reheating:** It should be emphasized that the dendrites are a phenomenon of alpha iron. They are formed in the temperature range below 1300 deg. F. The term "dendrite" is used in this connection to describe "a figure resembling a tree." Dendritic freezing and dendritic segregation are in no way implied. If the material is precipitated in alpha iron during slow cooling, it should redissolve upon reheating to some point below the box annealing temperature. Subsequent rapid cooling might prevent reprecipitation and the dendrites would thus disappear. The temperature at which solution would take place might be used as a clue to the identity of the material. Preliminary experiments showed that such was the case and indicated that cooling in air would be sufficiently rapid to prevent the reprecipitation of the material.

Accordingly a series of tests were made in which samples of a sheet containing dendrites were heated in a vacuum in a small tube furnace. For purposes of comparison a sample containing 0.10 per cent nitrogen, which showed large iron nitride plates, was treated at the same time. The specimens were polished and etched and the position of the dendrites and nitride plates noted before being placed in the furnace. After holding for two hours at temperature, the furnace tube was pulled out and allowed to cool in air. The specimens were than lightly repolished and examined, after which the same set went back into the furnace for treatment at a higher temperature. Results of these tests are shown in the table.

Table of Results of Reheating Tests

Sample	Structure previous to treating	Temp., Deg. F.*	Time, Hrs.	Structure after treatment
0.10% nitrogen sample. Box annealed.	Numerous large iron nitride plates.	600 (315)	2	No change.
		800 (426)	2	Noticeable solution. A few remnants of plates still present.
		850 (454)	2	Solution complete. No trace of plates at high magnification.
Sheet steel, box annealed 0.003% nitrogen.	Dendrites present in large quantities.	600 (315)	2	No change.
		800 (426)	2	No change.
		850 (454)	2	No change.
		900 (482)	2	No change.
		950 (510)	2	No change.
		1000 (538)	2	Possibly a few small dendrites gone. Large dendrites still present.
		1050 (565)	2	Noticeable solution. A few dendrites still present.
		1100 (595)	2	No trace of dendrites found at high powers. Solution complete.

* Deg. C. in parentheses.

The nitride plates were entirely gone at 850 deg. F. while the dendrites were not completely dissolved until 1100 deg. F. was reached. In Fig. 15 the nitrogen

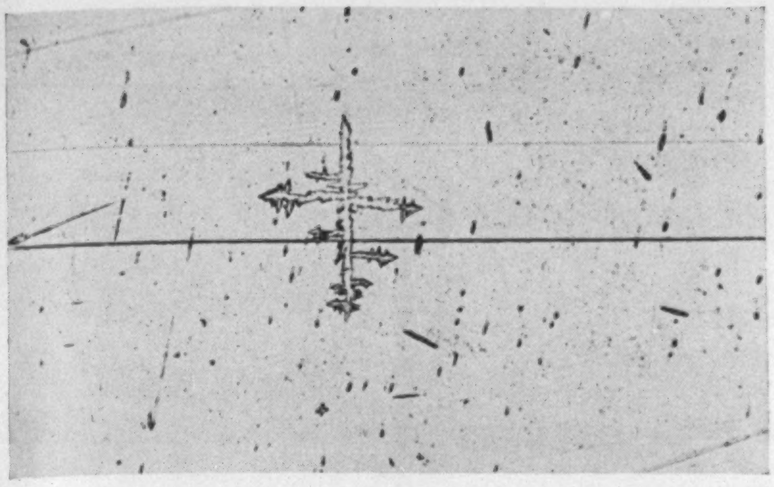


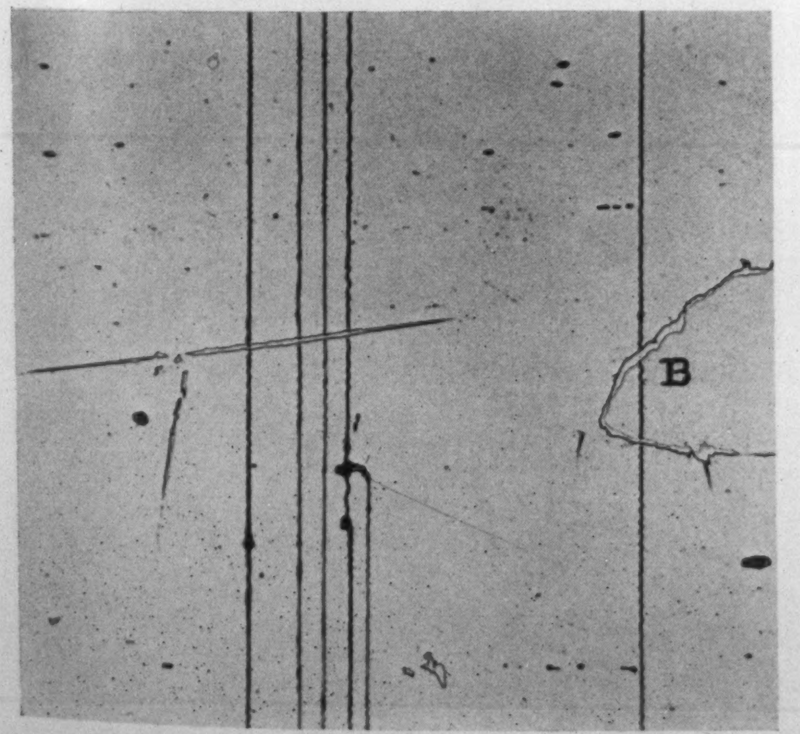
Fig. 17. Massin Dendrite Crossed by Polishing Scratches. Etched with 3 per cent nitric acid. Magnification 250 diameters.

content of the sheet steel and of the comparison sample has been plotted against the solution temperature and it appears very unlikely that the dendrites are iron nitride. The data are in better agreement with the iron carbon diagram as shown in Fig. 16. Here the temperature of solution has been plotted against the total carbon content of the steel, some of which is known to be at the grain boundaries. Deducting the grain boundary carbide would shift the plotted point to the left or towards the region of solid solubility in alpha iron.

(b). **Scratch Hardness and Etching Tests:** The thinness of the dendrites and their lace-like structure makes scratch testing rather difficult. Those developed in sheet bar by the treatment previously described are sometimes thicker and assume a more massive form. Fig. 17 shows one of this type. In Fig. 18 a massive dendrite is seen in cross section as a needle of appreciable thickness. Here scratch testing is entirely feasible and several scratches have been made across the needle. For comparison a scratch has been placed across the grain boundary carbide at B. The two seem to be equally hard. Fig. 19 shows the same spot after etching in hot alkaline sodium picrate. Both the needle and the grain boundary carbide are blackened. Murikami's Reagent gave similar results and similar etching effects have been obtained on all massive dendrites tested. The thin lace-like dendrites do not appear so black when examined at low powers, due no doubt to their delicate open structure.

(c). **Heating and Quenching Experiments:** The temperature of solution on reheating together with the etching results indicated rather strongly that the dendrites were composed of iron carbide. As a further check some tests were made by heating samples rapidly through the transformation range followed by quenching. With rapid heating, a mass of iron carbide in a matrix of iron should produce a local composition gradient whose steepness would depend on the rate of diffusion. If this local area could be brought above its transformation temperature quickly enough and quenched, characteristic transformation structures might result. The simultaneous existence, after quenching, of such structures around grain boundary carbide and around dendrites within the grains would be very good evidence in favor of iron carbide as the dendrite material. It will readily be seen that with a small particle of carbide, such as that represented by a single dendrite, the heating would need to be very rapid indeed. This rapid heating was accomplished by taking a sample of sheet steel one inch square and thrusting one corner into a welding torch flame. As soon as the extreme edge started to fuse the sample was dropped into water. The heating and cooling cycle thus occupied less than three seconds. Such a method produced a very steep temperature gradient near the corner of the sheet and at some point back from the fused zone conditions should be such that local transformation structures might exist as described. Fig. 20 shows the effect on the grain boundary carbide in such a region. Before heating, massive carbide similar to that shown at B in Fig. 18 occupied the center of these dark areas. Fig. 21 is a view of part of a large grain in which the heating conditions were satisfactory. A temperature gradient existed across this grain, the hotter side being to the left. The dark areas near C resulted from grain boundary carbide exactly as in Fig. 20. The dark area A resulted from transformation due to the material composing a dendrite. Another dendrite B, towards the cooler side of the grain,

Fig. 18. Diamond Scratch Test. Etched with 3 per cent nitric acid. Magnification 250 diameters.



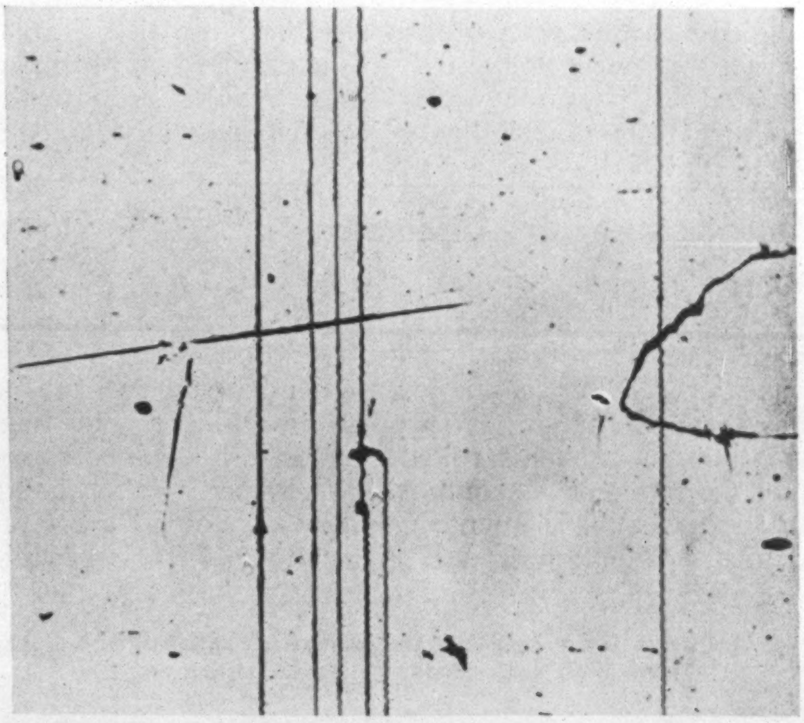


Fig. 19. Same as Fig. 18 after Etching in Alkaline Sodium Picrate. Magnification 250 diameters.

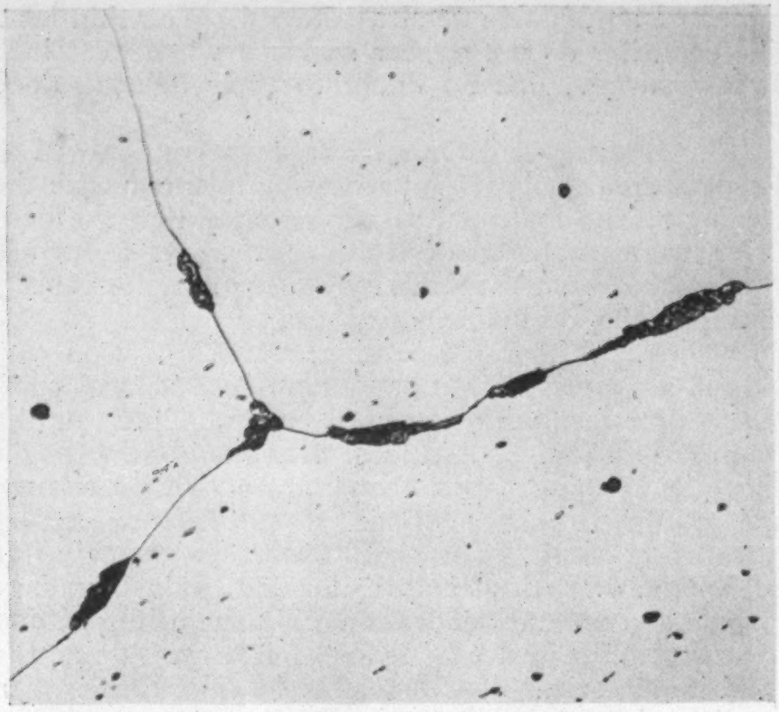


Fig. 20. Transformation Effect at Grain Boundary Carbide. Etched in 3 per cent nitric acid. Magnification 250 diameters.

has been slightly affected. Dendrites to the right of B were found to be in their original state.

Fig. 22 shows a detailed view of location A in Fig. 21. Scratch testing indicates that the dark area is slightly harder than the surrounding metal. Similar structures were obtained in a number of samples treated in the same way. These results support the etching tests and indicate iron carbide as the dendrite material.

Discussion

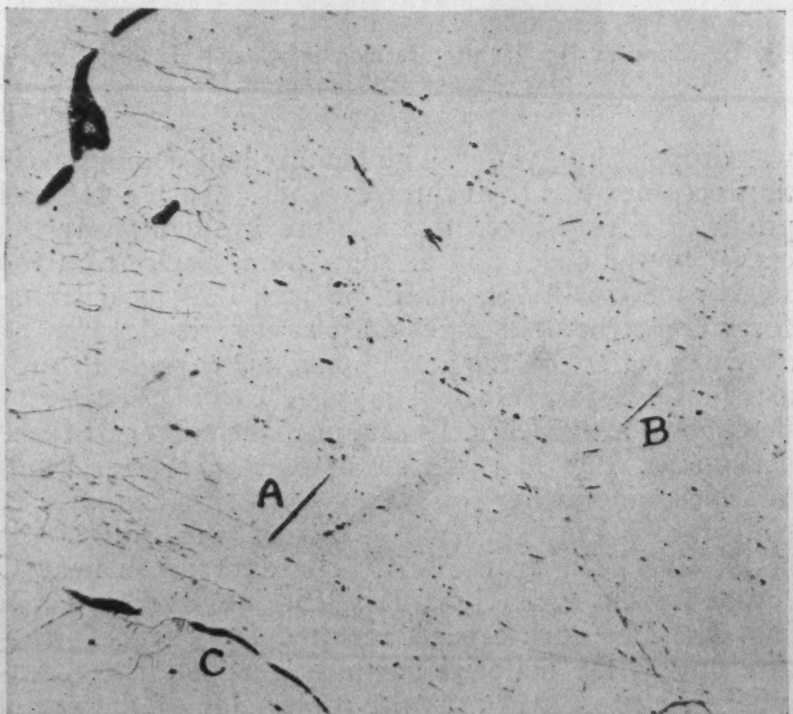
THE writers wish to point out the fact that the observations so far made do not represent a completed study. Many interesting points remain to be considered. For example, no dendrites have so far been found, after the proper mechanical and heat treatments, in sheets rolled from synthetic laboratory melts equivalent in composition to commercial sheets in so far as the elements usually determined are concerned. Whether or not this is due to the mechanical effects of greater reduction in commercial sheets or to something else is not known.

The relation of the dendrites, reported here, to the aging phenomenon in low carbon steels suggests itself at once. The box annealing treatment involves a cooling so slow that certainly little or no supersaturation can exist. The process allows abundant time for the precipitation of any material which shows a decreasing solubility with falling temperature.

Nitrogen has practically been eliminated as a possibility in our opinion because the known iron nitride plates in a 0.10 per cent N steel were dissolved at or slightly below 850 deg F. whereas the dendrites were not dissolved until some temperature higher than 1050 deg. F. was reached. Since solution takes place somewhere around 1050 or 1100 deg. F. it may be assumed, conversely, that precipitation at least begins at about this temperature range upon cooling down from the

(Continued on page 242)

Fig. 21. Large Grain Reheated and Quenched. Etched with 3 per cent nitric acd. Magnification 100 diameters.



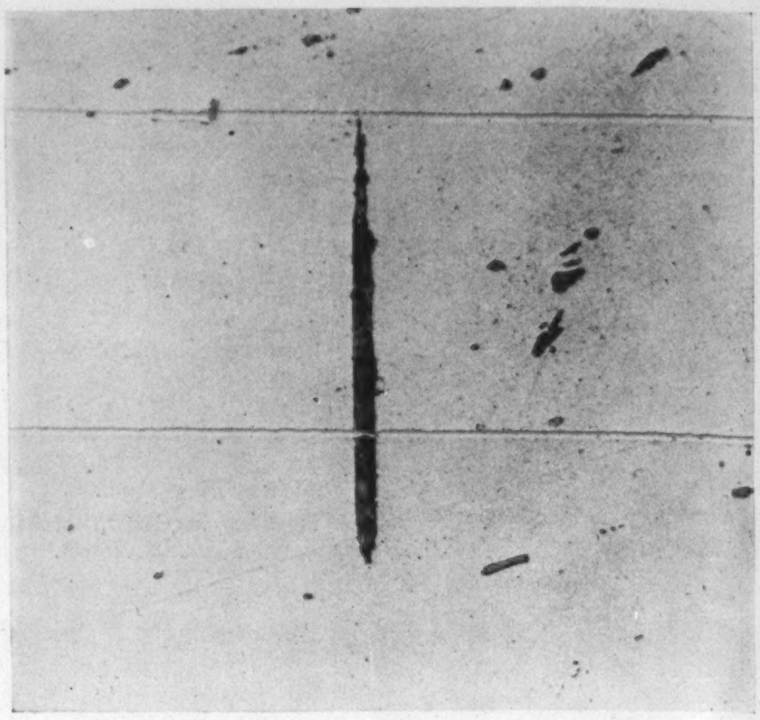
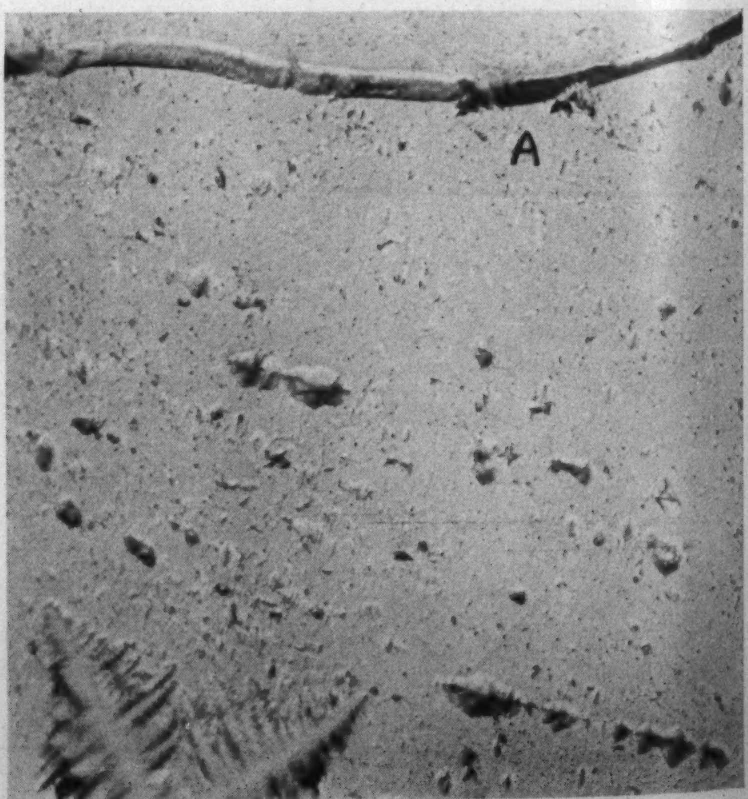


Fig. 22. Detail of Location A in Fig. 21. Magnification 500 diameters.

Fig. 23. Small Dendrites Associated with a Grain Boundary at A. Etched with 3 per cent nitric acid. Magnification 500 diameters.



BERYLLIUM AND ITS ALLOYS—III

A Correlated Abstract

By JACK DELMONTE, Sc. M.
East Lansdowne, Pa.

Concluded from the August issue

Cast Beryllium-Copper Alloys

Beryllium is replacing phosphorus in cast copper, since it has a powerful affinity for oxygen, sulphur, and other metalloids, improving the grain structure of the casting. Vacuum electric furnaces are recommended for preparing the melt.[46] Beryllium (0.01 to 0.02%) deoxidizes copper castings to give a smooth and flawless grain, in addition to improving the electrical conductivity[17]. The conductivity of the casting may be raised as much as 20 per cent by small amounts of beryllium, in addition to improved resistance to corrosion and erosion. Applications to pumps, liquid meters, and turbine blades are possible with this alloy[57].

A detailed description of the foundry practice is given by E. F. Cone[58]. The melt of copper is deoxidized either by boron carbide, calcium, lithium, or magnesium, so that beryllium will not be wasted in ridding the melt of excess oxygen. To the bath of copper is added the correct proportion of the master alloy (usually 12.5% Be-Cu). The pouring is conducted at a temperature of 1040 to 1090 deg. C., with the bath covered with charcoal. Green sand molds are satisfactory, with the casting shrinkage much less than aluminum bronze and approximately equal to phosphor-bronze. Linear shrinkage has been about 3/16 in. per ft. for the 2.5 per cent beryllium-copper. The castings have a rich, golden color, which enhances the final appearance. It is good practice to keep the casting at a temperature of 800 deg. C. for a couple of hours, if further fabrication is to be done, for in this state, the casting is in a soft annealed condition after quenching. The castings are now susceptible to heat treatment if they are of the correct composition, as outlined for the wrought beryllium-copper alloys. The castings should be properly supported during heat treatment, to prevent deformation. They should be heated in a non-oxidizing atmosphere if possible. Compared with steel, phosphor-bronze, and other high strength castings and materials, the electrical conductivity is quite high. Some average properties of castings are given in Table 7.[58]

Table 7.—Average Properties of Beryllium-Copper Castings

Composition	Elastic limit, p.s.i.	Tensile strength, p.s.i.	Elongation, per cent	Hardness, Brinell
As Cast:				
1.79% Be	42,600	61,800	7.0	110
1.36% Be	33,400	41,500	4.0	136
2.19% Be	44,800	60,500	10.0	120
Annealed:				
1.67% Be	16,810	41,100	29.0	54
1.79% Be	15,800	33,400	16.0	65
2.19% Be	22,500	40,000	12.0	110
Heat-Treated at 300°C.—3 hrs.:				
1.79% Be	39,000	71,100	3.0	119
2.19% Be	86,200	110,000	1.0	375
2.45% Be	95,600	117,000	1.0	415

The cost of the master beryllium-copper alloys has been given as follows:[45], [6],

Lots to 10 lbs.	$6.25
10-50 lbs.	4.25
50-200 lbs.	3.81

Miscellaneous Applications

The possible applications of beryllium-copper are manifold and may be easily arrived at after a study of their properties. A few important ones have already been given, as propeller hubs and watch mechanisms. Electrical accessories offer the greatest possibilities such as contact clips, contact springs, telegraph relay parts, thermostat controls, instrument springs, relay parts, brush holder springs, etc., which require good conductivity, resiliency, and resistance to fatigue. Parts of this description are illustrated in Figs. 8 and 9. Where good wearing qualities are desired,

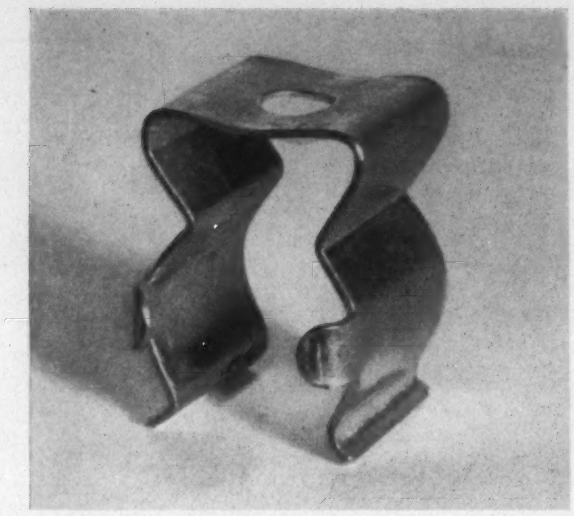


Fig. 8. Typical Fuse Clip of Beryllium-Copper Alloy. (Courtesy of American Brass Co.)

accompanied by good electrical conductivity and a minimum of arcing and burning, beryllium-copper answers the purpose of commutator segments, switches, electrical contact surfaces, etc. Beryllium-copper springs may be easily soldered or brazed; typical springs are illustrated in Fig. 10.

Worm gears of beryllium-copper have proven more satisfactory than steel on the shaft of a sewing machine.[59] They possess excellent wear qualities, high strength, and resistance to shock loads. On one textile machine they showed no signs of wear after a service period of eight months, while its predecessor, bronze gears, had a life of about four months.[54]

Annealed beryllium-copper wires of small size may be woven into cloth and subsequently heat treated[60]. The cloth becomes stiff and strong, with the tensile strength of the individual strands greatly raised.

Henry Ford is reported as using the alloy in breaker points on his cars. Because of its high resistance to impact, beryllium-copper is also used as firing pins in firearms[47,61]. Ordinary pins of alloy steel did not last more than 33 min. in an accelerated test, while beryllium-copper stood up 7 hrs.

Valve parts, line valves in petroleum industry (because of excellent corrosion resistance in this application), chilled rifle bar nuts for rock drills, worm driving gears for jaw riveting machines, and boat propellers are other uses of beryllium-copper[58].

Non-sparking tools of every description have been manufactured from beryllium-copper. The property of non-sparking is of value in paint shops, powder factories, gas works, petroleum wells, refineries, or at other places where exist serious fire hazards.[21,62,48]. Though not as durable as steel tools of similar design and size, beryllium-copper tools are remarkable in their sparkless characteristics. It has been found that wrought beryllium-copper is better for tools than the cast alloy[62]. In sharpening the tools, care must be observed not to overheat the tools and draw the temper.

Further attention is called to the beryllium-copper-cobalt alloys.[53] In combining strength and conductivity, this group of alloys is able to withstand a great deal of heat without losing the temper. Applications that have been undertaken are: Springs for mechanical and electrical loads where there is excessive heat; welding electrodes to carry high current under heavy mechanical pressure; soldering iron tips; and pole shaders, where conductivity and fatigue strength are required at elevated temperatures.

The list of applications is growing: Handles for surgical instruments that can be easily chromium-plated; non-magnetic characteristics utilized in instruments;[54] etc. These applications emphasize the fact that beryllium-copper alloys are of major consequence, with a promising future.

Beryllium Steels

Though beryllium steels have not achieved the success which the beryllium-copper alloys have, it is advisable to outline the previous research on these steels in an effort to furnish some clues for future work. Particularly outstanding in this work has been W. Kroll, consulting metallurgist, Siemens & Halske, Germany. Binary beryllium-iron alloy with 1.2 per cent beryllium, age hardens very slightly; but with 3.9 per cent beryllium the alloy age hardens to 370 Brinell[13]. However, they are quite brittle and unsatisfactory. The brittleness that accompanies a number of beryllium steels prompted pessimistic comments from the research department of English Steel Corp., Ltd., and Messrs. Thos. Firth and John Brown, Ltd.[63]. They reported that beryllium additions to steel were of little or no use to the group of metals in the manufacture of special steels. In addition, a beryllium-steel was reported to be unsatisfactory as a bearing metal[64] because it was too fragile.

W. Kroll points out that the addition of nickel to binary beryllium-steels is of distinct advantage, insofar as the grain size is modified. Beryllium additions to nickel-free steels result in brittle alloys. At least 5 per cent nickel to 1 per cent beryllium is necessary for a fine grain structure. Even in the presence of adequate nickel the hardening properties of beryllium do not better those of carbon, and the nickel-steels respond better to carbon. There have been poor results with the addition of beryllium to 18 and 8 stainless steels, as far as corrosion resistance is concerned. The influence of beryllium in the presence of carbon is unsatisfactory in such steels. Nevertheless, the one redeeming feature is the fact that the chromium-nickel stainless steels have had the hardness increased to 680 Brinell on the addition of beryllium[65]. In Table 8 are given a few of the outstanding beryllium steels and their characteristics, together with the source of information:

Fig. 9. Electrical Terminal Lugs and Miscellaneous Parts of Beryllium-Copper Alloys. (Courtesy of American Brass Co.)

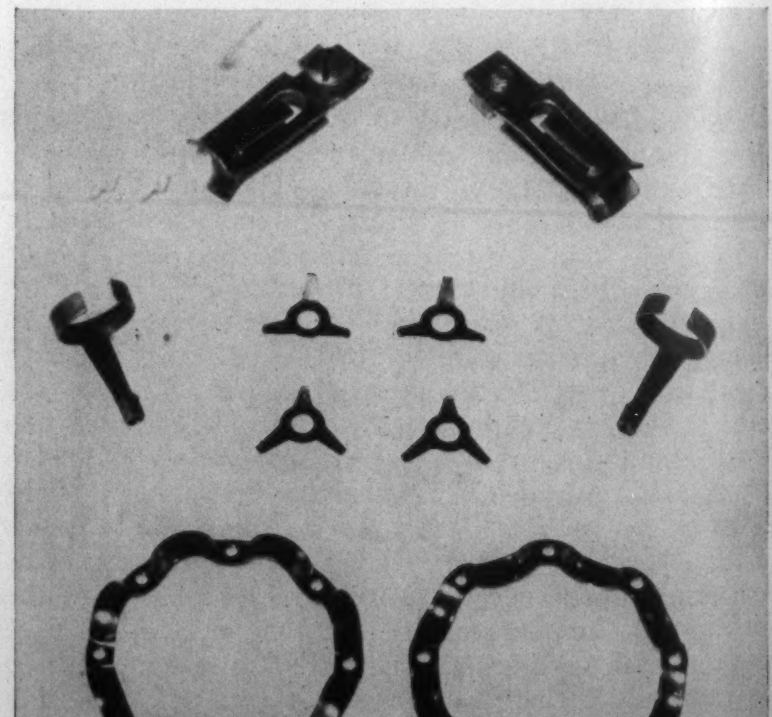


Table 8.—Beryllium Steels

Composition	Characteristics	Reference
5% Ni, 1.1% Be, 12% Cr Fe	680 Brinell, good corrosion resistance	65
36% Ni, 1% Be Fe........	Similar to invar steels, low susceptibility to oxidation after aging	13
20% Cr, 5% Ni, 1% Be Fe	Temper of high speed steel after aging	43
18% Cr, 8% Ni, 1% Be Fe	Precipitation hardening	66

Beryllium brings about age-hardening in carbon-free iron. This may be more easily recognized by referring to Fig. 11, which graphically illustrates the effect of age-hardening on binary beryllium steel. The beryllium steels are hardened as effectively as carbon steels by a comparatively low temperature treatment[67]. The magnetic properties of ternary and quaternary beryllium steels are improved by heat treatment. In the case of quaternary Fe-Ni-Cr-Be, the presence of chromium enhances the effect of nickel.

It is possible to roll iron with a high sulphur content after the addition of beryllium, and yet have the sulphur content of the sheet well beyond the red-short limitation[68]. A strip with 0.76 per cent sulphur and 0.53 per cent beryllium has been rolled without flaws and edge cracks. There is a chemical reaction between the beryllium and the sulphur to form beryllium sulphide, which may be removed as slag from the melt and reprocessed to recover the beryllium. To insure that all the beryllium may react with the steel, the steel should be carefully deoxidized. When the beryllium sulphide content is low, it is distributed throughout the melt as "inclusions." Beryllium is recognized as one of the most powerful de-oxidizing and desulphurizing agents for use with steels.

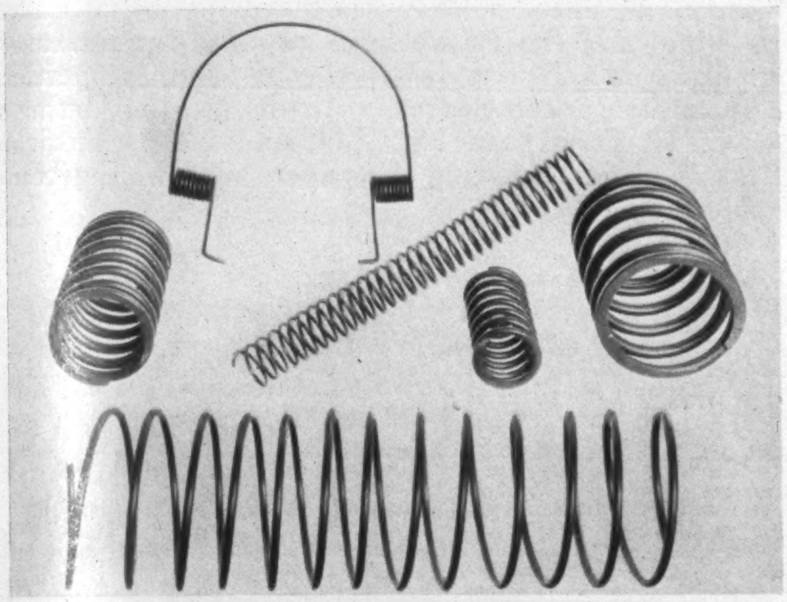


Fig. 10. Typical Springs of Beryllium-Copper. (Courtesy of American Brass Co.)

Alloys of Beryllium with Nickel and Silver

The alloys of beryllium and silver have been investigated in Great Britain and the United tates. Recognizing the affinity of beryllium for sulphur, investigators have hoped to develop tarnish proof silver for silverware. An early patent to Cooper stated that 3 to 5 per cent Be in silver rendered silver immune to the action of sulphur compounds. Sloman tries to achieve the same with a smaller amount of beryllium, and was granted a patent governing the use of up to 1 per cent Be with silver[69]. The British Institute of Metals, before which Sloman addressed his paper, urged that further work be conducted along this line of investigation.

Beryllium-nickel alloys show great promise inasmuch as they respond as readily to heat treatment and age-hardening as do the copper-beryllium alloys. The physical properties may be improved by quenching at 1000 to 1100 deg. C., and reheating to 450 deg. C.[13]. The tensile strengths are as follows: Soft annealed, 115,000 lbs. per sq. in.; heat-treated from soft state, 176,000 lbs. per sq. in.; hard-rolled, 219,000 lbs. per sq. in.; and heat treated from hard rolled, 259,000 lbs. per sq. in.[48]. In the last condition there is an elongation of 8 per cent.

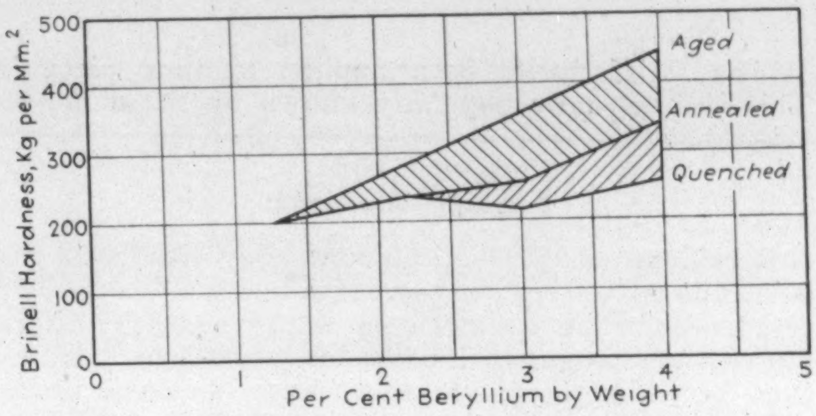


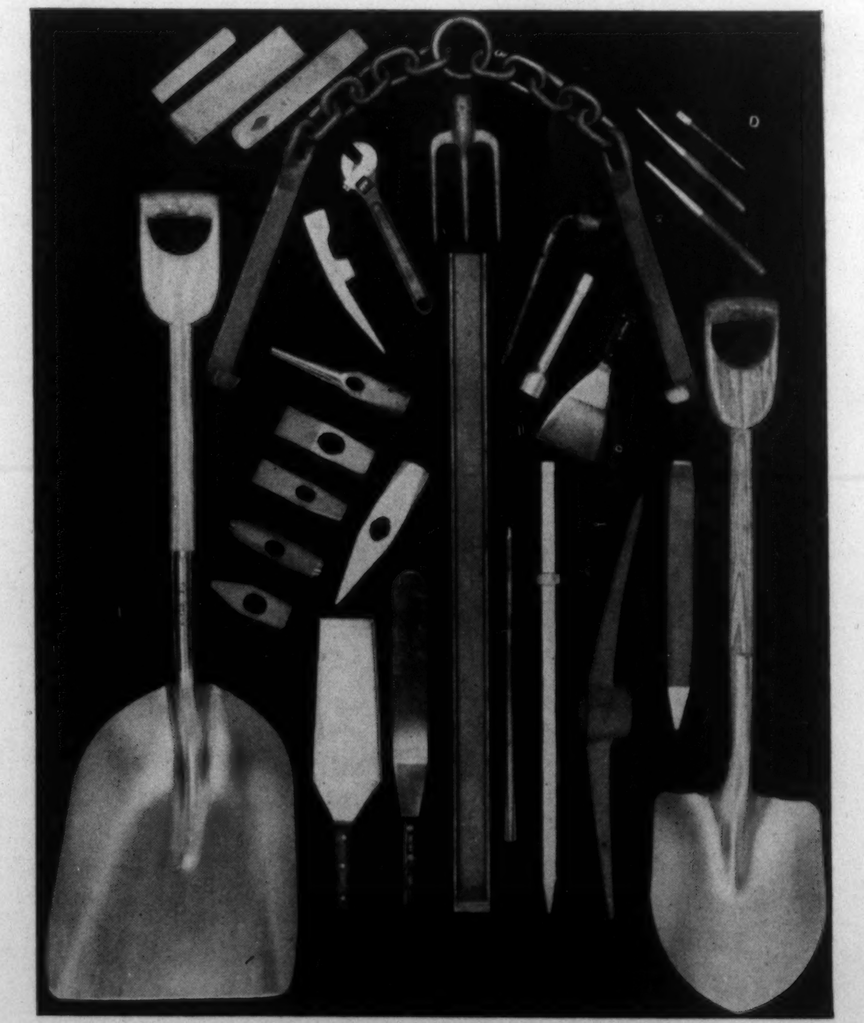
Fig. 11. Age Hardening of Binary Iron-Beryllium Alloys. (Siemens-Konzern).

Balance wheels of watches have been successfully built of beryllium-nickel and have proved feasible.[6] Beryllium is recommended for deoxidizing nickel castings.[45].

Beryllium Contracid

A German alloy of the composition 0.6 Be, 60 Ni, 15 Cr, 7 per cent Mo, and the remainder Fe, has exhibited some useful properties. It is quenched in water or oil from a temperature of 1050 deg. C., and heat treated at about 400 deg. C. after hard rolling.[48]

Fig. 12. Group of Sparkless Working Tools. (Courtesy of Ampco Metal Co., Inc., Milwaukee).



It has satisfactorily been applied to time pieces.[56] This alloy is more popularly known by the name of "Contracid."

Beryllium-Aluminum

Beryllium (2.5%)—Aluminum alloy has been reported as possessing good strength and good corrosion resistance; while as much as 7 per cent Be raises the tensile strength to 100,000 lbs. per sq. in.[15] However, beryllium-aluminum alloys have not come up to expectation in physical properties, though there has been no difficulty in preparing castings of any composition. Efforts to improve aluminum alloys of 5 per cent copper, by the addition of small amounts of beryllium, show negative results with no apparent effect on the physical properties.[13]

Two United States patents for beryllium-aluminum alloys are noted[6] Beryllium (55-70%), aluminum (25 to 40%), and Mn, Mo, V, or Zr (0.5-2.5%), U. S. Patent No. 1,905,312 specified the use of the alloy for pistons. For airplane construction, the U. S. Patent No. 1,924,168, calls for beryllium (25-40%), aluminum (55-70%), and max. Mo 2 per cent. In both of these examples the extreme lightness is the outstanding feature of the alloy. This point has been emphasized by others, who claim that beryllium-aluminum alloys may prove a decisive factor in national defense; as airplanes having one-fourth the weight and yet the strength of steel may be built[57].

Be-Mg and Be-Si Alloys

It has not been possible to prepare an alloy of the Be-Mg type, as the magnesium boils before the melting point of beryllium is reached, and beryllium does not dissolve in liquid magnesium.

Beryllium-silicon alloys are very hard and unusually brittle. They have been investigated by Masing and Dahl[13]. The composition of the eutectic in the constitutional diagram is 39 per cent beryllium and 61 per cent silicon at 1095 deg. C.

In conclusion, the author wishes to emphasize the fact that an attempt has been made to bring out the salient features of the metallurgical processes of beryllium and beryllium alloys. Considerable progress has been made since industry has taken this metal under its wing, and the future holds promise for increased applications and new discoveries of useful properties. The author acknowledges, with thanks, the kindness of C. H. Davis and Mr. Silliman of the American Brass Co., in reviewing the paper, and offering comments.

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(Continued from page 238)

maximum box annealing temperature. The hydrogen-purified sheets showed an abundance of dendrites and yet contained only 0.0088 per cent nitrogen whereas the solubility of nitrogen at 1050 deg. F., the temperature at which precipitation must start, is close to one-half of one per cent.

The precipitation of an iron-oxygen compound along the slip planes of the ferrite crystals as explained in a recent paper by Davenport and Bain[1], should not be overlooked. In strain aging, of course, the urge to precipitate is supplied by cold working. The iron-oxygen diagram shows decreasing solubility with a lowering of the temperature, and hence, some precipitation might take place during the box annealing cycle. In this connection it should be mentioned that all sheets so far examined have been from basic open-hearth rimmed steel which is known to be high in oxygen content. It is thought however, that the elevation of the dendrites after ordinary etching, their color, hardness, and local reaction upon heating rapidly through the transformation range eliminates such a compound from consideration.

The evidence indicating that the dendrites are composed of iron carbide seems quite conclusive. It should be mentioned that Whiteley[2] in 1927 reported the precipitation of cementite along certain planes in ferrite grains; see his Figs. 10 and 11. His cooling rate was probably too rapid to induce precipitation on the scale found in box annealed material. A few instances have been observed in which small dendrites occur right in the grain boundaries. Fig. 23 shows such an example. It has previously been mentioned that free iron carbide was known to exist in the grain boundaries after box annealing.

We would not be justified in assuming that the dendrites are idiomorphic crystals of cementite. It is more likely that they represent a compromise between the natural habit of cementite and the restrictions imposed by precipitation along certain planes in ferrite crystals. No complete crystallographic investigation of the large ferrite grains has been undertaken.

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